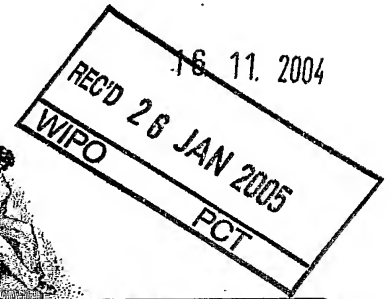


PA 1175895



# THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

May 27, 2004

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM  
THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK  
OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT  
APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A  
FILING DATE UNDER 35 USC 111.

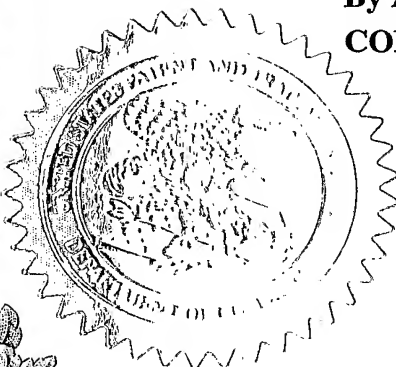
APPLICATION NUMBER: 60/532,331

FILING DATE: December 22, 2003

## PRIORITY DOCUMENT

SUBMITTED OR TRANSMITTED IN  
COMPLIANCE WITH RULE 17.1(a) OR (b)

By Authority of the  
COMMISSIONER OF PATENTS AND TRADEMARKS



H. L. JACKSON

Certifying Officer

PATENT APPLICATION SERIAL NO. \_\_\_\_\_

U.S. DEPARTMENT OF COMMERCE  
PATENT AND TRADEMARK OFFICE  
FEE RECORD SHEET

01/02/2004 BSAYASI1 00000068 082336 60532331

01 FC:1005 160.00 DA

PTO-1556  
(5/87)

\*U.S. Government Printing Office: 2002 — 489-267/69033


Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

# PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a **PROVISIONAL APPLICATION FOR PATENT** under 37 CFR 1.53(c).

Express Mail Label N .

ER583872078US

INVENTOR(S)					
Given Name (first and middle (if any))	Family Name or Surname	Residence (City and either State or Foreign Country)			
Ilya E.	Nifant'ev	Moscow, Russia			
Pavel V.	Ivchenko	Moscow, Russia			
Ilya V.	Tajdakov	Moscow, Russia			
<input checked="" type="checkbox"/> Additional inventors are being named on the <u>1</u> separately numbered sheets attached hereto					
TITLE OF THE INVENTION (500 characters max)					
METALLOCENE COMPOUNDS					
Direct all correspondence to: CORRESPONDENCE ADDRESS					
<input checked="" type="checkbox"/> Customer Number		34872			
OR		Type Customer Number here		34872	
<input type="checkbox"/> Firm or Individual Name		William R. Reid			
Address		Basell USA Inc.			
Address		912 Appleton Road			
City		Elkton	State	MD	ZIP 21921
Country		US	Telephone	410-996-1783	Fax 410-996-1560
ENCLOSED APPLICATION PARTS (check all that apply)					
<input checked="" type="checkbox"/> Specification		Number of Pages		38	<input type="checkbox"/> CD(s), Number
<input type="checkbox"/> Drawing(s)		Number of Sheets			<input type="checkbox"/> Other (specify)
<input type="checkbox"/> Application Data Sheet		See 37 CFR 1.76			
METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT					
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27.				FILING FEE AMOUNT (\$)	
<input type="checkbox"/> A check or money order is enclosed to cover the filing fees					
<input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number:		08-2336		\$160.00	
<input type="checkbox"/> Payment by credit card. Form PTO-2038 is attached.					
The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.					
<input checked="" type="checkbox"/> No.					
<input type="checkbox"/> Yes, the name of the U.S. Government agency and the Government contract number are: _____					

Respectfully submitted,

SIGNATURE

*William R. Reid*

TYPED or PRINTED NAME William R. Reid

TELEPHONE 410-996-1783

Date 12/22/2003

REGISTRATION NO.  
(if appropriate)  
Docket Number:

47,894

FE 6156 (US)

## USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

This collection of information is required by 37 CFR 1.51. The information is used by the public to file (and by the PTO to process) a provisional application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the complete provisional application to the PTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Washington, D.C. 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Box Provisional Application, Assistant Commissioner for Patents, Washington, D.C. 20231.

**PROVISIONAL APPLICATION COVER SHEET**  
**Additional Page**

PTO/SB/16 (02-01)  
Approved for use through 10/31/2002. OMB 0651-0032  
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

<table border="1" style="display: inline-table;"><tr><td style="padding: 2px 5px;">Docket Number</td><td style="padding: 2px 5px;">FE 6156 (US)</td></tr></table>			Docket Number	FE 6156 (US)
Docket Number	FE 6156 (US)			
INVENTOR(S)/APPLICANT(S)				
Given Name (first and middle (if any))	Family or Surname	Residence (City and either State or Foreign Country)		
Luigi	Resconi	Ferrara, Italy		

Number   2   of   2  

**WARNING:** Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

**EXPRESS MAILING CERTIFICATE**

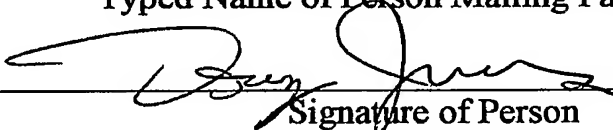
This certifies that the attached **Form PTO/SB/16** (in duplicate), **Specification (38)** for the provisional application of **Ilya E. Nifant'ev et al.**, for **METALLOCENE COMPOUNDS** (our ref: **FE 6156 (US)**) is being mailed by "Express Mail Post Office to Addressee" service in an envelope addressed:

Mail Stop Provisional Patent Application  
Commissioner for Patents  
P. O. Box 1450  
Alexandria, VA 22313-1450

and deposited on **DECEMBER 22, 2003** as "Express Mail" in the United States Postal Service, the number of the "Express Mail" mailing label being **ER573872078US**.

Douglas Jumps

\_\_\_\_\_  
Typed Name of Person Mailing Paper or Fee

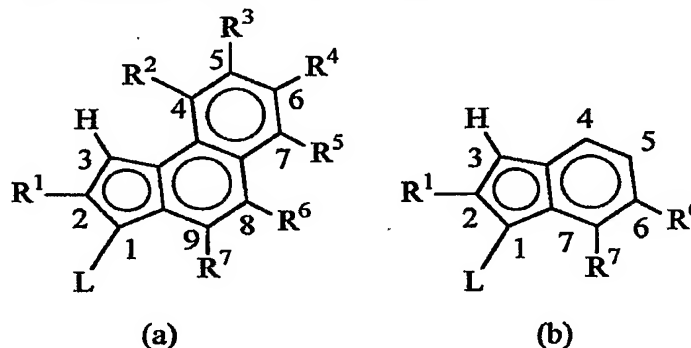
  
\_\_\_\_\_  
Signature of Person

**METALLOCENE COMPOUNDS**

The present invention relates to metallocene compounds containing a benzoindenyl moiety having a well-defined substitution pattern. The invention further relates to the use of said metallocene compounds as catalyst components for the polymerization of olefins and the

5 polymerization process thereof.

For the purpose of the present invention the numeration of the positions of the benzoindenyl and indenyl moieties is as set forth below in the moieties of formula (a) and (b):



Metallocene compounds containing a benzoindenyl moiety are known from US 5,830,821. However, even if in this document the general formula embraces a plethora of substituted

10 benzoindenyl-containing metallocene compounds, the compounds exemplified are not substituted in position 5 of the benzoindenyl ring.

EP 754 698 discloses dimethylsilylene(2,7-dimethyl-4,5-(2-methyl-benzo)-1-indenyl)(2,7-di-*t*-butyl-9-fluorenyl)zirconium dichloride. As reported in table 1 this compound has a polymerization activity lower than the correspondent unsubstituted benzoindenyl

15 compound.

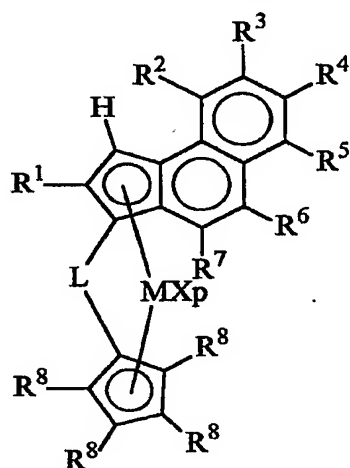
US 6,228,795 reports, in a long list of compounds, phenyl(methyl)silandiylbis(2-methyl-4,5-(methylbenzo)-1-indenyl)Zr(CH<sub>3</sub>)<sub>2</sub>, and phenyl(methyl)silandiylbis(2-methyl-4,5-(tetramethylbenzo)-1-indenyl)Zr(CH<sub>3</sub>)<sub>2</sub>. In the first compound no indications are given about the position of the methyl group, that on the contrary as shown in the comparative examples of the

20 present invention is important for improving the activity of these metallocene compounds when used in polymerization reactions.

The applicant found that it is possible to increase the polymerization activity of a metallocene compound containing a 4,5-benzoindenyl moiety, when it is used as catalyst

component for the polymerization of olefins, by substituting the 4,5-benzoindenyl moiety in position 5.

An object of the present invention is a metallocene compound of formula (I):



(I)

wherein:

- 5 M is an atom of a transition metal selected from those belonging to group 3, 4, 5, 6 or to the lanthanide or actinide groups in the Periodic Table of the Elements; preferably M is titanium, zirconium or hafnium;
- p is an integer from 0 to 3, preferably p is 2, being equal to the formal oxidation state of the metal M minus 2;
- 10 X, same or different, is a hydrogen atom, a halogen atom, or a R, OR, OSO<sub>2</sub>CF<sub>3</sub>, OCOR, SR, NR<sub>2</sub> or PR<sub>2</sub> group, wherein R is a C<sub>1</sub>-C<sub>40</sub> hydrocarbon group optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably R is a linear or branched, cyclic or acyclic, C<sub>1</sub>-C<sub>40</sub>-alkyl, C<sub>2</sub>-C<sub>40</sub> alkenyl, C<sub>2</sub>-C<sub>40</sub> alkynyl, C<sub>6</sub>-C<sub>40</sub>-aryl, C<sub>7</sub>-C<sub>40</sub>-alkylaryl or C<sub>7</sub>-C<sub>40</sub>-arylalkyl radicals; optionally containing heteroatoms belonging to groups 13-17
- 15 of the Periodic Table of the Elements; or two X can optionally form a substituted or unsubstituted butadienyl radical or a OR'O group wherein R' is a divalent radical selected from C<sub>1</sub>-C<sub>40</sub> alkylidene, C<sub>6</sub>-C<sub>40</sub> arylidene, C<sub>7</sub>-C<sub>40</sub> alkylarylidene and C<sub>7</sub>-C<sub>40</sub> arylalkylidene radicals; preferably X is a hydrogen atom, a halogen atom or a R group; more preferably X is chlorine or a methyl radical;
- 20 L is a divalent bridging group selected from C<sub>1</sub>-C<sub>20</sub> alkylidene, C<sub>3</sub>-C<sub>20</sub> cycloalkylidene, C<sub>6</sub>-C<sub>20</sub> arylidene, C<sub>7</sub>-C<sub>20</sub> alkylarylidene, or C<sub>7</sub>-C<sub>20</sub> arylalkylidene radicals optionally containing

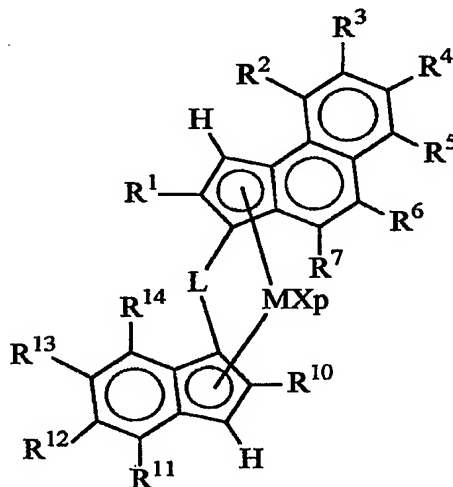
- heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements, and silylidene radical containing up to 5 silicon atoms such as  $\text{SiMe}_2$ ,  $\text{SiPh}_2$ ; preferably L is a group  $\text{Z(R'')}_2$  wherein Z is a carbon or a silicon atom, and R'' is a linear or branched, cyclic or acyclic,  $\text{C}_1$ - $\text{C}_{10}$ -alkyl,  $\text{C}_2$ - $\text{C}_{10}$  alkenyl,  $\text{C}_2$ - $\text{C}_{10}$  alkynyl,  $\text{C}_6$ - $\text{C}_{10}$ -aryl,  $\text{C}_7$ - $\text{C}_{10}$ -alkylaryl or  $\text{C}_7$ - $\text{C}_{10}$ -arylalkyl radicals optionally
- 5 containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; more preferably the group  $\text{Z(R'')}_2$  is  $\text{Si}(\text{CH}_3)_2$ ,  $\text{SiPh}_2$ ,  $\text{SiPhMe}$ ,  $\text{SiMe}(\text{SiMe}_3)$ ,  $\text{CH}_2$ ,  $(\text{CH}_2)_2$ , and  $\text{C}(\text{CH}_3)_2$ ;  $\text{R}^1$  is a  $\text{C}_1$ - $\text{C}_{40}$  hydrocarbon group optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably  $\text{R}^1$  is a linear or branched, cyclic or acyclic,  $\text{C}_1$ - $\text{C}_{40}$ -alkyl,  $\text{C}_2$ - $\text{C}_{40}$  alkenyl,  $\text{C}_2$ - $\text{C}_{40}$  alkynyl,  $\text{C}_6$ - $\text{C}_{40}$ -aryl,  $\text{C}_7$ - $\text{C}_{40}$ -alkylaryl or  $\text{C}_7$ - $\text{C}_{40}$ -arylalkyl radical;
- 10 optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; more preferably  $\text{R}^1$  is linear or branched, saturated or unsaturated  $\text{C}_1$ - $\text{C}_{20}$ -alkyl radical; even more preferably  $\text{R}^1$  is a methyl, an ethyl or an isopropyl radical;
- $\text{R}^3$  is a  $\text{C}_1$ - $\text{C}_{40}$  hydrocarbon group optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably  $\text{R}^3$  is a linear or branched, cyclic or acyclic,  $\text{C}_1$ - $\text{C}_{40}$ -alkyl,  $\text{C}_2$ - $\text{C}_{40}$  alkenyl,  $\text{C}_2$ - $\text{C}_{40}$  alkynyl,  $\text{C}_6$ - $\text{C}_{40}$ -aryl,  $\text{C}_7$ - $\text{C}_{40}$ -alkylaryl or  $\text{C}_7$ - $\text{C}_{40}$ -arylalkyl radical;
- 15 optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; more preferably  $\text{R}^3$  is linear or branched, saturated or unsaturated  $\text{C}_1$ - $\text{C}_{20}$ -alkyl or a  $\text{C}_6$ - $\text{C}_{40}$ -aryl, radical; even more preferably  $\text{R}^3$  is a methyl, an ethyl or a phenyl radical;
- $\text{R}^2$ ,  $\text{R}^4$  and  $\text{R}^5$ , equal to or different from each other, are hydrogen atoms or  $\text{C}_1$ - $\text{C}_{40}$  hydrocarbon groups optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the
- 20 Elements; with the proviso that least one among  $\text{R}^2$ ,  $\text{R}^4$  and  $\text{R}^5$  is a hydrogen atom; preferably  $\text{R}^2$ ,  $\text{R}^4$  and  $\text{R}^5$ , equal to or different from each other, are hydrogen atoms or linear or branched, cyclic or acyclic,  $\text{C}_1$ - $\text{C}_{40}$ -alkyl,  $\text{C}_2$ - $\text{C}_{40}$  alkenyl,  $\text{C}_2$ - $\text{C}_{40}$  alkynyl,  $\text{C}_6$ - $\text{C}_{40}$ -aryl,  $\text{C}_7$ - $\text{C}_{40}$ -alkylaryl or  $\text{C}_7$ - $\text{C}_{40}$ -arylalkyl radicals; optionally containing heteroatoms belonging to groups 13-17 of the Periodic
- 25 Table of the Elements; with the proviso that least one among  $\text{R}^2$ ,  $\text{R}^4$  and  $\text{R}^5$  is a hydrogen atom; more preferably  $\text{R}^2$ ,  $\text{R}^4$  and  $\text{R}^5$  are hydrogen atoms;
- $\text{R}^3$  with  $\text{R}^4$  and/or  $\text{R}^4$  with  $\text{R}^5$  can also join to form a aliphatic or aromatic 3-7 membered ring optionally containing heteroatoms belonging to groups 13-16 of the Periodic Table of the Elements; said ring can bear one or more hydrocarbon substituents having from 1 to 20 carbon atoms;
- 30  $\text{R}^6$  and  $\text{R}^7$ , equal to or different from each other, are hydrogen atoms or  $\text{C}_1$ - $\text{C}_{40}$  hydrocarbon groups optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;



preferably  $R^6$  and  $R^7$ , equal to or different from each other, are hydrogen atoms or linear or branched, cyclic or acyclic,  $C_1$ - $C_{40}$ -alkyl,  $C_2$ - $C_{40}$  alkenyl,  $C_2$ - $C_{40}$  alkynyl,  $C_6$ - $C_{40}$ -aryl,  $C_7$ - $C_{40}$ -alkylaryl or  $C_7$ - $C_{40}$ -arylalkyl radicals; optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; more preferably  $R^6$  and  $R^7$  are hydrogen atoms or linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl radicals; even more preferably  $R^6$  and  $R^7$  are hydrogen atoms or a methyl radicals;

$R^8$ , equal to or different from each other, are hydrogen atoms or  $C_1$ - $C_{50}$  hydrocarbon groups optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; two or more  $R^8$  groups can also join together to form one or more 3-7 membered rings, said rings contain at least one heteroatom belonging to groups 13-16 of the Periodic Table of the Elements; said rings can be further substituted with  $C_1$ - $C_{20}$  hydrocarbon groups optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;

A subclass of the compound of formula (I) is a compound of formula (II)



(II)

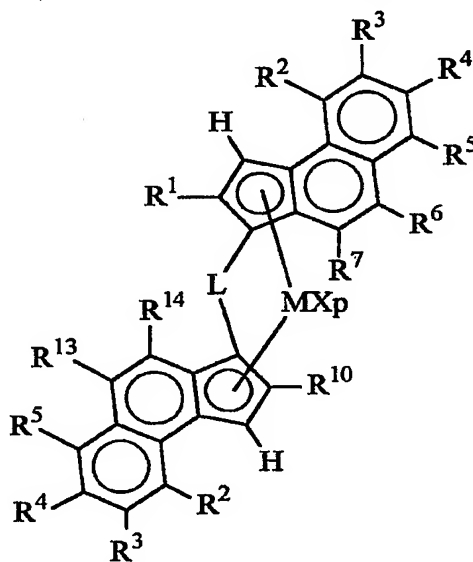
wherein  $M$ ,  $X$ ,  $p$ ,  $L$ ,  $R^1$ ,  $R^2$ ,  $R^3$ ,  $R^4$ ,  $R^5$ ,  $R^6$  and  $R^7$  have been described above;

$R^{10}$  is, a hydrogen atom or  $C_1$ - $C_{40}$  hydrocarbon group optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably  $R^{10}$  is a hydrogen atom or a linear or branched, cyclic or acyclic,  $C_1$ - $C_{40}$ -alkyl,  $C_2$ - $C_{40}$  alkenyl,  $C_2$ - $C_{40}$  alkynyl,  $C_6$ - $C_{40}$ -aryl,  $C_7$ - $C_{40}$ -alkylaryl or  $C_7$ - $C_{40}$ -arylalkyl radical; optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; more preferably  $R^{10}$  is a linear or branched  $C_1$ - $C_{20}$ -alkyl

radical such as a methyl radical, an ethyl radical or an isopropyl radical; preferably  $R^1$  and  $R^{10}$  are not branched  $C_1$ - $C_{40}$ -alkyl radical at the same time.

- $R^{11}$ ,  $R^{12}$ ,  $R^{13}$  and  $R^{14}$ , equal to or different from each other, are hydrogen atoms or  $C_1$ - $C_{40}$  hydrocarbon groups optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably  $R^{11}$ ,  $R^{12}$ ,  $R^{13}$  and  $R^{14}$ , equal to or different from each other, are hydrogen atoms or linear or branched, cyclic or acyclic,  $C_1$ - $C_{40}$ -alkyl,  $C_2$ - $C_{40}$  alkenyl,  $C_2$ - $C_{40}$  alkynyl,  $C_6$ - $C_{40}$ -aryl,  $C_7$ - $C_{40}$ -alkylaryl or  $C_7$ - $C_{40}$ -arylalkyl radicals; optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; two adjacent  $R^{11}$ ,  $R^{12}$ ,  $R^{13}$  and  $R^{14}$  groups can also join to form a 3-7 membered ring optionally containing heteroatoms belonging to groups 13-16 of the Periodic Table of the Elements; said ring can bear one or more hydrocarbon substituents having from 1 to 20 carbon atoms; more preferably  $R^{11}$  is a  $C_6$ - $C_{40}$ -aryl,  $C_7$ - $C_{40}$ -alkylaryl or  $C_7$ - $C_{40}$ -arylalkyl radical or form with  $R^{12}$  a phenyl ring that can be substituted with hydrocarbon groups having from 1 to 20 carbon atoms; more preferably  $R^{12}$  is a hydrogen atoms or form with  $R^{11}$  3-7 membered ring as explained above; more preferably  $R^{14}$  and  $R^{13}$  are hydrogen atoms or  $C_1$ - $C_{20}$  alkyl radicals.

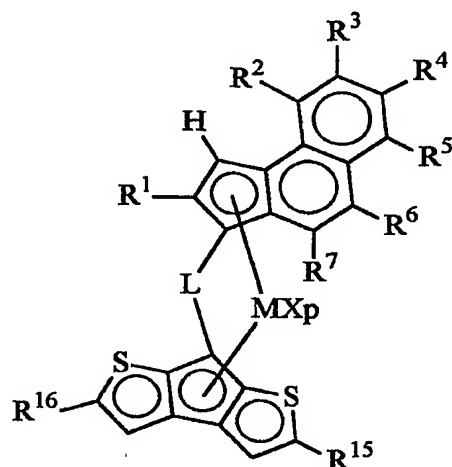
A preferred class of compounds of formula (II) is a compound of formula (III)



(III)

wherein M, X, p, L,  $R^1$ ,  $R^2$ ,  $R^3$ ,  $R^4$ ,  $R^5$ ,  $R^6$ ,  $R^7$ ,  $R^{10}$ ,  $R^{13}$  and  $R^{14}$  have been described above.

A further subclass of the compound of formula (I) is a compound of formula (IV)

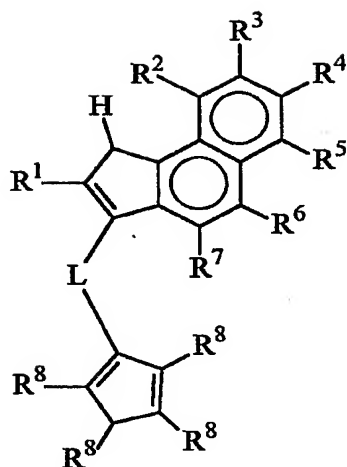


(IV)

wherein M, X, p, L, R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, R<sup>5</sup>, R<sup>6</sup> and R<sup>7</sup> have been described above; R<sup>15</sup> and R<sup>16</sup>, equal to or different from each other, are hydrogen atoms or C<sub>1</sub>-C<sub>40</sub> hydrocarbon groups optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably R<sup>15</sup> and R<sup>16</sup>, equal to or different from each other, are hydrogen atoms or linear or branched, cyclic or acyclic, C<sub>1</sub>-C<sub>40</sub>-alkyl, C<sub>2</sub>-C<sub>40</sub> alkenyl, C<sub>2</sub>-C<sub>40</sub> alkynyl, C<sub>6</sub>-C<sub>40</sub>-aryl, C<sub>7</sub>-C<sub>40</sub>-alkylaryl or C<sub>7</sub>-C<sub>40</sub>-arylalkyl radicals; optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; more preferably R<sup>15</sup> and R<sup>16</sup> are linear or branched C<sub>1</sub>-C<sub>40</sub>-alkyl radicals optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements such as methyl, ethyl, isopropyl or trimethylsilyl radicals.

The metallocene compounds of formula (I) can be obtained with the process comprising the following steps:

(a) contacting the compound of formula (Ia)



(Ia)

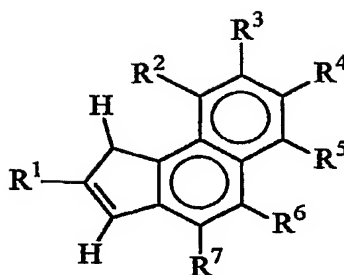
and/or its double bond isomers

wherein  $R^1$ ,  $R^2$ ,  $R^3$ ,  $R^4$ ,  $R^5$ ,  $R^6$ ,  $R^7$ ,  $R^8$  and L have the meaning described above with a base selected from  $T_jB$ ,  $TMgT^1$ , sodium and potassium hydride, metallic sodium and potassium, wherein B is an alkaline or alkali-earth metal; and j is 1 or 2, j being equal to 1 when B is an alkaline metal, preferably lithium, and j being equal to 2 when B is an alkali-earth metal; T is a linear or branched, cyclic or acyclic,  $C_1$ - $C_{20}$ -alkyl,  $C_6$ - $C_{20}$ -aryl,  $C_7$ - $C_{20}$ -alkylaryl or  $C_7$ - $C_{20}$ -arylalkyl radical, optionally containing one or more Si or Ge atoms; preferably T is methyl or butyl radical;  $T^1$  is an halogen atom or a group  $OR''$  wherein  $R''$  is a linear or branched, cyclic or acyclic,  $C_1$ - $C_{40}$ -alkyl,  $C_6$ - $C_{40}$ -aryl,  $C_7$ - $C_{40}$ -alkylaryl or  $C_7$ - $C_{40}$ -arylalkyl radical, optionally containing one or more heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably  $T^1$  is an halogen atom, more preferably bromine; wherein the molar ratio between said base and the ligand of the formula (Ia) and is at least 2:1; excess of said base can be used; and

- a) contacting the product obtained in step a) with a compound of formula  $MX_{p+2}$  wherein M, X and p have the meaning described above.

The ligands of formula (Ia) can be obtained with a process comprising the following steps:

- a) contacting a compound of formula (VI):



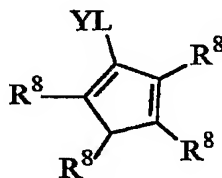
(VI)

and/or its double bond isomer

wherein  $R^1$ ,  $R^2$ ,  $R^3$ ,  $R^4$ ,  $R^5$ ,  $R^6$  and  $R^7$  are defined as above;

with a base selected from  $T_jB$ ,  $TMgT^1$ , sodium and potassium hydride, metallic sodium and potassium; wherein T, j, B and  $T^1$  are defined as above, and wherein the molar ratio between said base and the compound of the formula (VI) is at least 1:1; excess of said base can be used;

b) contacting the anionic compound obtained in step a) with a compound of formula (VII):

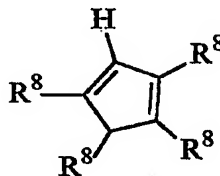


(VII)

wherein  $R^8$  and L are defined as above and Y is chlorine, bromine and iodine, preferably Y is chlorine or bromine.

10 An alternative process for preparing the ligand of formula (I) comprises the following steps:

a) contacting a compound of formula (VIIa):



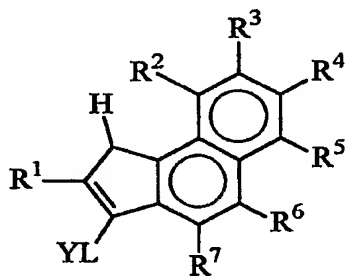
(VIIa)

and/or its double bond isomer

wherein  $R^8$  is defined as above;

with a base selected from  $T_jB$ ,  $TMgT^1$ , sodium and potassium hydride, metallic sodium and potassium; wherein T, j, B and  $T^1$  are defined as above, and wherein the molar ratio between said base and the compound of the formula (VIIa) is at least 1:1; excess of said base can be used;

- 5 b) contacting the anionic compound obtained in step a) with a compound of formula (VIa):

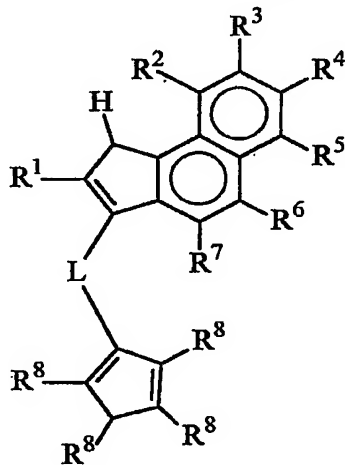


(VIa)

wherein  $R^1$ ,  $R^2$ ,  $R^3$ ,  $R^4$ ,  $R^5$ ,  $R^6$ ,  $R^7$  and L are defined as above and Y is chlorine, bromine and iodine, preferably Y is chlorine or bromine.

- The above processes are preferably carried out in an aprotic solvent, either polar or apolar. Said aprotic solvent is preferably an aromatic or aliphatic hydrocarbon, optionally halogenated, or an ether; more preferably it is selected from benzene, toluene, pentane, hexane, heptane, cyclohexane, dichloromethane, diethylether, tetrahydrofurane and mixtures thereof. The above process is carried out at a temperature ranging from  $-100^\circ\text{C}$  to  $+80^\circ\text{C}$ , more preferably from  $-20^\circ\text{C}$  to  $+70^\circ\text{C}$ .

A further object of the present invention is a ligand of formula (Ia)

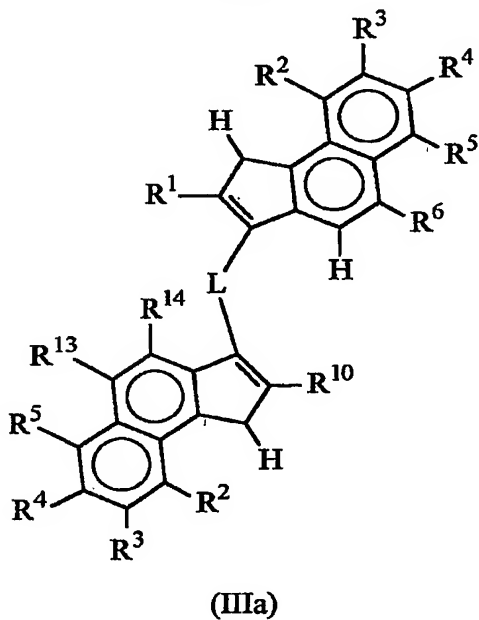
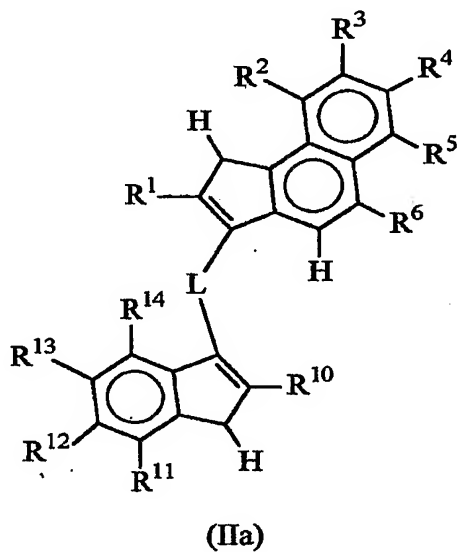


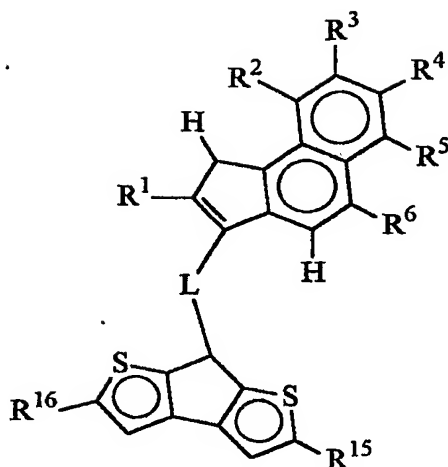
(Ia)

and/or its double bond isomers

wherein  $R^1$ ,  $R^2$ ,  $R^3$ ,  $R^4$ ,  $R^5$ ,  $R^6$ ,  $R^7$ ,  $R^8$  and L have the meaning described above.

5 Metalocene compounds of formulas (II) (III) (IV) can be prepared by using the process described above starting respectively from the ligands of formulas (IIa), (IIIa) and (IVa) and/or their double bonds isomers:





(IVa)

wherein L, R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, R<sup>5</sup>, R<sup>6</sup>, R<sup>7</sup>, R<sup>8</sup>, R<sup>9</sup>, R<sup>10</sup>, R<sup>11</sup>, R<sup>12</sup>, R<sup>13</sup>, R<sup>14</sup>, R<sup>15</sup> and R<sup>16</sup>, have been described above.

The ligand of formulas (IIa), (IIIa), and (IVa) can be prepared according to the process described above by using the corresponding starting compounds.

- 5        The compounds of formula (VI) and (VIa) can be prepared according to US 5,830,821, by using the opportunely substituted naphthalene moiety as starting compound.

The metallocene compounds object of the present invention can be used as catalyst components for obtaining a catalyst system for the polymerization of olefins. Therefore a further object of the present invention is a catalyst system obtainable by contacting:

- 10    a)    at least a metallocene compound of formula (I);  
       b)    at least an alumoxane or a compound able to form an alkylmetallocene cation; and  
       c)    optionally an organo aluminum compound.

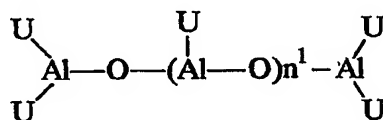
Preferably at least a metallocene compound of formulas (II), (III) and (IV) is used.

- 15    Alumoxanes used as component b) can be obtained by reacting water with an organo-aluminium compound of formula H<sub>j</sub>AlU<sub>3-j</sub> or H<sub>j</sub>Al<sub>2</sub>U<sub>6-j</sub>, where the U substituents, same or different, are hydrogen atoms, halogen atoms, C<sub>1</sub>-C<sub>20</sub>-alkyl, C<sub>3</sub>-C<sub>20</sub>-cycloalkyl, C<sub>6</sub>-C<sub>20</sub>-aryl, C<sub>7</sub>-C<sub>20</sub>-alkylaryl or C<sub>7</sub>-C<sub>20</sub>-arylalkyl radicals, optionally containing silicon or germanium atoms, with the proviso that at least one U is different from halogen, and j ranges from 0 to 1, being also a non-integer number. In this reaction the molar ratio of Al/water is preferably comprised between 1:1 and 100:1.

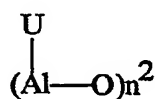


The molar ratio between aluminium and the metal of the metallocene is generally comprised between about 10:1 and about 30000:1, preferably between about 100:1 and about 5000:1.

- 5 The alumoxanes used in the catalyst according to the invention are considered to be linear, branched or cyclic compounds containing at least one group of the type:



wherein  $n^1$  is 0 or an integer of from 1 to 40 and the substituents U are defined as above; and/or a group of the type:



in the case of cyclic compounds, wherein  $n^2$  is an integer from 2 to 40 and the U substituents are defined as above.

- 10 Examples of alumoxanes suitable for use according to the present invention are methylalumoxane (MAO), tetra-(isobutyl)alumoxane (TIBAO), tetra-(2,4,4-trimethyl-pentyl)alumoxane (TIOAO), tetra-(2,3-dimethylbutyl)alumoxane (TDMBAO) and tetra-(2,3,3-trimethylbutyl)alumoxane (TTMBAO).

- 15 Particularly interesting cocatalysts are those described in WO 99/21899 and in WO01/21674 in which the alkyl and aryl groups have specific branched patterns.

- Non-limiting examples of aluminium compounds that can be reacted with water to give suitable alumoxanes (b), described in WO 99/21899 and WO01/21674, are:
- 20 tris(2,3,3-trimethyl-butyl)aluminium, tris(2,3-dimethyl-hexyl)aluminium, tris(2,3-dimethyl-butyl)aluminium, tris(2,3-dimethyl-pentyl)aluminium, tris(2,3-dimethyl-heptyl)aluminium, tris(2-methyl-3-ethyl-pentyl)aluminium, tris(2-methyl-3-ethyl-hexyl)aluminium, tris(2-methyl-3-ethyl-heptyl)aluminium, tris(2-methyl-3-propyl-hexyl)aluminium, tris(2-ethyl-3-methyl-butyl)aluminium, tris(2-ethyl-3-methyl-pentyl)aluminium, tris(2,3-diethyl-pentyl)aluminium, tris(2-propyl-3-methyl-butyl)aluminium, tris(2-isopropyl-3-methyl-butyl)aluminium, tris(2-isobutyl-3-methyl-pentyl)aluminium, tris(2,3,3-trimethyl-pentyl)aluminium, tris(2,3,3-trimethyl-hexyl)aluminium,
- 25 tris(2-ethyl-3,3-dimethyl-butyl)aluminium, tris(2-ethyl-3,3-dimethyl-pentyl)aluminium, tris(2-isopropyl-3,3-dimethyl-butyl)aluminium, tris(2-trimethylsilyl-propyl)aluminium, tris(2-methyl-3-

phenyl-butyl)aluminium, tris(2-ethyl-3-phenyl-butyl)aluminium, tris(2,3-dimethyl-3-phenyl-butyl)aluminium, tris(2-phenyl-propyl)aluminium, tris[2-(4-fluoro-phenyl)-propyl]aluminium, tris[2-(4-chloro-phenyl)-propyl]aluminium, tris[2-(3-isopropyl-phenyl)-propyl]aluminium, tris(2-phenyl-butyl)aluminium, tris(3-methyl-2-phenyl-butyl)aluminium, tris(2-phenyl-pentyl)aluminium, tris[2-(pentafluorophenyl)-propyl]aluminium, tris[2,2-diphenyl-ethyl]aluminium and tris[2-phenyl-2-methyl-propyl]aluminium, as well as the corresponding compounds wherein one of the hydrocarbyl groups is replaced with a hydrogen atom, and those wherein one or two of the hydrocarbyl groups are replaced with an isobutyl group.

Amongst the above aluminium compounds, trimethylaluminium (TMA), triisobutylaluminium (TIBA), tris(2,4,4-trimethyl-pentyl)aluminium (TIOA), tris(2,3-dimethylbutyl)aluminium (TDMBA) and tris(2,3,3-trimethylbutyl)aluminium (TTMBA) are preferred.

Non-limiting examples of compounds able to form an alkylmetallocene cation are compounds of formula  $D^+E^-$ , wherein  $D^+$  is a Brønsted acid, able to donate a proton and to react irreversibly with a substituent X of the metallocene of formula (I) and  $E^-$  is a compatible anion, which is able to stabilize the active catalytic species originating from the reaction of the two compounds, and which is sufficiently labile to be removed by an olefinic monomer. Preferably, the anion  $E^-$  comprises one or more boron atoms. More preferably, the anion  $E^-$  is an anion of the formula  $BAr_4^{(-)}$ , wherein the substituents Ar which can be identical or different are aryl radicals such as phenyl, pentafluorophenyl or bis(trifluoromethyl)phenyl. Tetrakis-pentafluorophenyl borate is particularly preferred compound, as described in WO 91/02012. Moreover, compounds of formula  $BAr_3$  can be conveniently used. Compounds of this type are described, for example, in the International patent application WO 92/00333. Other examples of compounds able to form an alkylmetallocene cation are compounds of formula  $BAr_3P$  wherein P is a substituted or unsubstituted pyrrol radical. These compounds are described in WO01/62764. Compounds containing boron atoms can be conveniently supported according to the description of DE-A-19962814 and DE-A-19962910. All these compounds containing boron atoms can be used in a molar ratio between boron and the metal of the metallocene comprised between about 1:1 and about 10:1; preferably 1:1 and 2:1; more preferably about 1:1.

Non limiting examples of compounds of formula  $D^+E^-$  are:  
Triethylammoniumtetra(phenyl)borate,

- Tributylammoniumtetra(phenyl)borate,
- Trimethylammoniumtetra(tolyl)borate,
- Tributylammoniumtetra(tolyl)borate,
- Tributylammoniumtetra(pentafluorophenyl)borate,
- 5 Tributylammoniumtetra(pentafluorophenyl)aluminate,
- Tripropylammoniumtetra(dimethylphenyl)borate,
- Tributylammoniumtetra(trifluoromethylphenyl)borate,
- Tributylammoniumtetra(4-fluorophenyl)borate,
- N,N-Dimethylbenzylammonium-tetrakis(pentafluorophenyl)borate,
- 10 N,N-Dimethylhexylammonium-tetrakis(pentafluorophenyl)borate,
- N,N-Dimethylaniliniumtetra(phenyl)borate,
- N,N-Diethylaniliniumtetra(phenyl)borate,
- N,N-Dimethylaniliniumtetrakis(pentafluorophenyl)borate,
- N,N-Dimethylaniliniumtetrakis(pentafluorophenyl)aluminate,
- 15 N,N-Dimethylbenzylammonium-tetrakis(pentafluorophenyl)borate,
- N,N-Dimethylhexylammonium-tetrakis(pentafluorophenyl)borate,
- Di(propyl)ammoniumtetrakis(pentafluorophenyl)borate,
- Di(cyclohexyl)ammoniumtetrakis(pentafluorophenyl)borate,
- Triphenylphosphoniumtetrakis(phenyl)borate,
- 20 Triethylphosphoniumtetrakis(phenyl)borate,
- Diphenylphosphoniumtetrakis(phenyl)borate,
- Tri(methylphenyl)phosphoniumtetrakis(phenyl)borate,
- Tri(dimethylphenyl)phosphoniumtetrakis(phenyl)borate,
- Triphenylcarbeniumtetrakis(pentafluorophenyl)borate,
- 25 Triphenylcarbeniumtetrakis(pentafluorophenyl)aluminate,
- Triphenylcarbeniumtetrakis(phenyl)aluminate,
- Ferroceniumtetrakis(pentafluorophenyl)borate,
- Ferroceniumtetrakis(pentafluorophenyl)aluminate.
- Triphenylcarbeniumtetrakis(pentafluorophenyl)borate, and
- 30 N,N-Dimethylaniliniumtetrakis(pentafluorophenyl)borate.

Organic aluminum compounds used as compound c) are those of formula  $H_3AlU_{3-j}$  or

$H_2Al_2U_{6-j}$  as described above.

The catalyst system object of the present invention can be used for (co)polymerizing one or more olefins. Therefore a further object of the present invention is a process for (co)polymerizing olefins containing from 2 to 20 carbon atoms comprising contacting one or more of said olefins under polymerization conditions in the presence of the catalyst system described above. Preferably alpha-olefins containing from 2 to 20 carbon atoms are used.

Examples of alpha-olefins that can be used with the process of the present invention are: ethylene, propylene, 1-butene, 1-pentene, 4-methyl-1-pentene, 1-hexene, 1-octene, 4,6-dimethyl-1-heptene, 1-decene, 1-dodecene, 1-tetradecene, 1-hexadecene, 1-octadecene and 1-eicosene. Preferred olefins are propylene, ethylene and 1-butene.

The following examples are given for illustrative purpose and do not intend to limit the invention.

### **EXAMPLES**

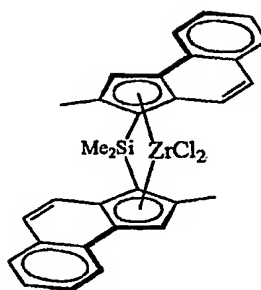
#### **General procedures**

All operations were performed under nitrogen by using conventional Shlenk-line techniques. Solvents were purified by degassing with nitrogen and passing over activated  $Al_2O_3$  and stored under nitrogen. All compounds were analyzed by  $^1H$ -NMR and  $^{13}C$ -NMR on a DPX 200 Bruker spectrometer. Due to the low solubility of the Zirconocene, the  $^{13}C$ -NMR spectra of this compound were performed on a Bruker DPX 400 in  $CD_2Cl_4$  at 120° C.

The melting points of the polymers ( $T_m$ ) were measured by Differential Scanning Calorimetry (D.S.C.) on Perkin Elmer DSC-7 instrument, according to the standard method. A weighted sample (5-10 mg) obtained from the polymerization was sealed into aluminum pans and heated at 200°C with a scanning speed corresponding to 20°C/minute. The sample was kept at 200°C for 5 minutes to allow a complete melting of all the crystallites. Successively, after cooling to 0°C with a scanning speed corresponding to 20°C/minute the sample was kept for 5 minutes at 0°C. Then the sample was heated for the second time at 200°C with a scanning speed corresponding to 10°C/min. In this second heating run, the peak temperature was taken as the melting temperature ( $T_m$ ).

#### **Comparative example 1**

(dimethyl)silanediybis(4,5-benzo-indenyl)Zirconiumdichloride (C1)

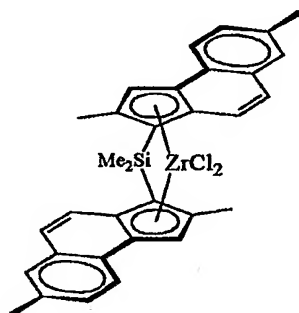


(C1)

was prepared according to the procedure described in US 5,830,821.

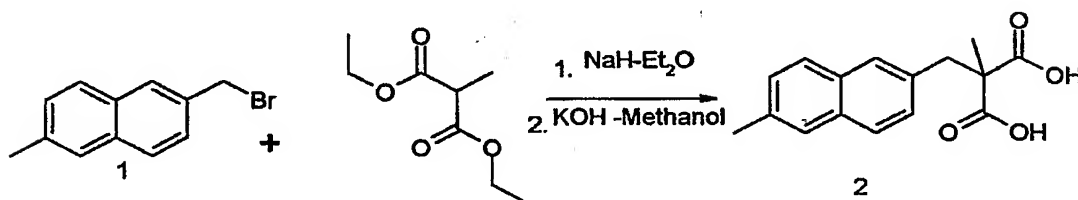
### Comparative example 2

### Synthesis of (dimethyl)silanedibis(2,7-dimethyl-3H-cyclopenta[a]naphthalen-1-yl)ZrCl<sub>2</sub> (C2)



(C2)

#### 5 a) 2-methyl-2-[(6-methyl-2-naphthyl)methyl]malonic acid

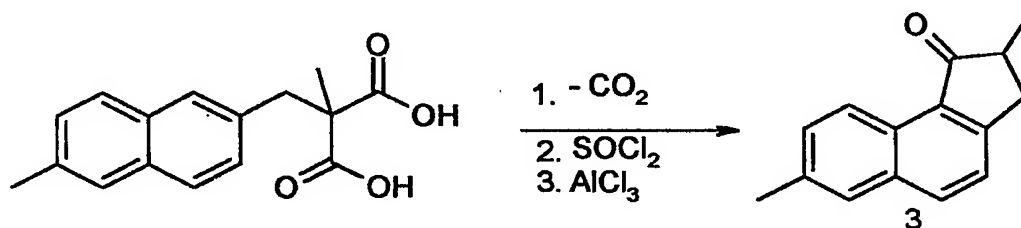


To a stirred suspension of 3.6 g NaH (90 mmol, 60 % in mineral oil) in 200 ml Et<sub>2</sub>O 16.2 ml (94 mmol) of diethyl 2-methylmalonate was added slowly with cooling. After 2 h stirring at 20 C, solution of 21.2 g (90 mmol) of 2-(bromomethyl)-6-methylnaphthalene (prepared according *Buu-Hoi L.; J.Chem.Soc.; 1946; 831*) in 30 ml of THF was added, resulting mixture was stirred overnight and decomposed by addition of saturated NH<sub>4</sub>Cl solution. Organic phase was separated, aqueous - extracted twice with 100 ml portions of ether. Combined extracts were

evaporated, residue was dissolved in 150 ml methanol and solution of KOH (20 g, 360 mmol) was added slowly. Mixture was refluxed for 5 h, then evaporated to dryness and resulting semisolid was dissolved in warm water (400 ml). Solution was extracted three times with 100 ml portions of ether, then acidified by carefully addition of 10 % HCl. Precipitate of acid 2 was collected and dried, yielded 20 g (81 %) of white powder.

**<sup>1</sup>H NMR (dmso -d<sub>6</sub>):** 12.9 (broad s, 2H), 7.72 (m, 2H), 7.62 (d, 2H), 7.33 (m, 2H), 3.3 (s, 2H), 2.4 (s, 3H), 1.25 (s, 3H).

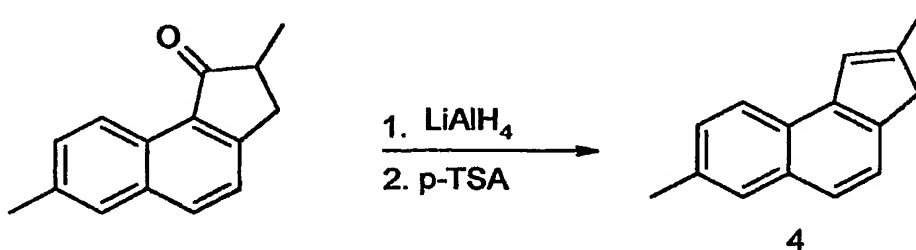
**b) 2,7-dimethyl-2,3-dihydro-1H-cyclopenta[a]naphthalen-1-one**



Acid 2 (20 g, 73 mmol) was heated to 180 C without solvent until gas evolving ceased (10 min), then reaction mixture was cooled, dissolved in benzene (50 ml) and evaporated. Oily residue was again dissolved in benzene (100 ml) and treated with SOCl<sub>2</sub> (16 ml, 219 mmol). Resulting solution was refluxed 3 h, evaporated to dryness and dissolved in 100 ml of dry CH<sub>2</sub>Cl<sub>2</sub>. This solution was added dropwise at 0 C to stirred suspension of 14.5 g (109 mmol) anhydrous AlCl<sub>3</sub> in 50 ml of CH<sub>2</sub>Cl<sub>2</sub>. Reaction mixture was stirred overnight, poured into ice-5 % HCl solution and extracted twice with 50 ml of CH<sub>2</sub>Cl<sub>2</sub>. Combined organic extracts were washed with KHCO<sub>3</sub> solution, dried over MgSO<sub>4</sub> and evaporated, afforded 11.4g (74 %) of 3 as brown semisolid.

**<sup>1</sup>H NMR (CDCl<sub>3</sub>):** 9.05 (d, 1H), 7.95 (d, 1H), 7.68 (s, 1H), 7.52 (d, 1H), 7.45 (d, 2H), 3.45 (qwart, 1H), 2.8 (m, 2H), 2.55 (s, 3H), 1.40 (d, 3H).

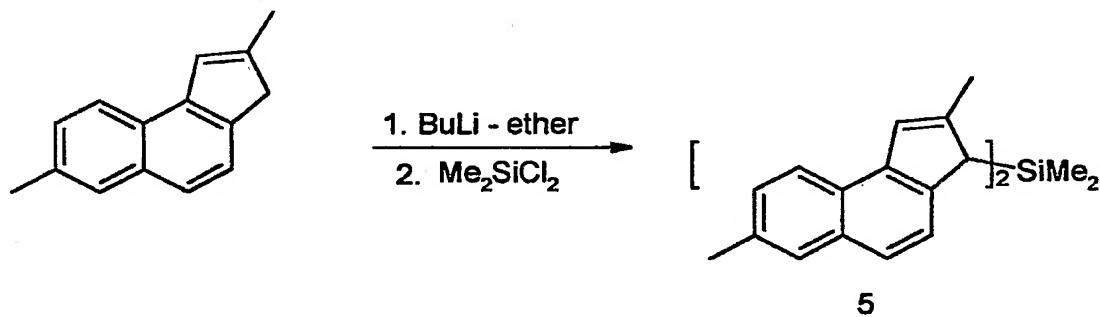
**c) 2,7-dimethyl-3H-cyclopenta[a]naphthalene**



To a suspension of 0.54 g (14 mmol)  $\text{LiAlH}_4$  in 50 ml  $\text{Et}_2\text{O}$  solution of 10g (48 mmol) of **3** in ether was added slowly with stirring at 0 C. Reaction mixture was stirred at room temperature for 4 h, then decompose by addition of saturated  $\text{NH}_4\text{Cl}$  solution. Organic layer was separated, evaporated and resulting oil was dissolved in 250 ml of benzene. Small amount (100 mg) of p-TSA was added and solution was refluxed with Dean-Stark water trap for 1h. Reaction was monitored by TLC (benzene). Dark solution was cooled, washed with saturated  $\text{KHCO}_3$  solution, dried over  $\text{MgSO}_4$ , filtered through  $\text{Al}_2\text{O}_3$  (Fluka, neutral, grade I) layer and evaporated. Yield of **4** (two isomers) as light semisolid - 8.1 g (87 %).

**$^1\text{H}$ NMR ( $\text{CDCl}_3$ ):** 8.05 (d, 1H), 7.85 (d, 1H), 7.74 (m, 3H), 7.64 (m, 2H), 7.55 (d, 1H), 7.4 (m, 2H), 7.15 ("s", 1H), 6.7 ("s", 1H), 3.65 (s, 2H), 3.55 (s, 2H), 2.63 (d, 6H), 2.33 (d, 6H).

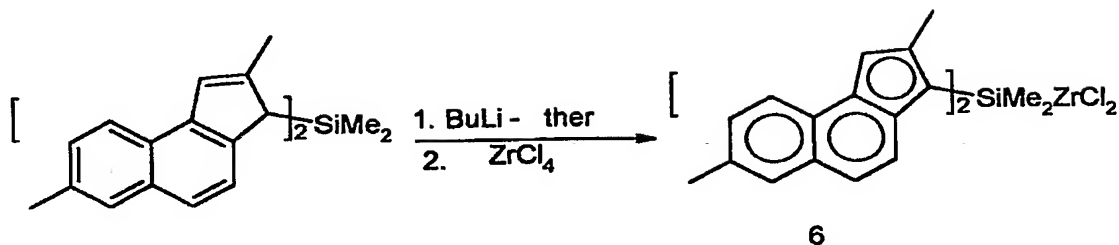
**d) bis(2,7-dimethyl-3*H*-cyclopenta[*a*]naphthalen-1-yl)(dimethyl)silane**



Lithium salt of **4** was prepared in usual manner from 5 g (25.7 mmol) of **4** and 17 ml (27.2 mmol) n-BuLi (Merck, 1.6 N solution in hexanes) in 75 ml  $\text{Et}_2\text{O}$  at -30 C. Then reaction mixture was warmed to 20 C, stirred 5 h and again cooled to -70 C. At this temperature 130 mg (1.4 mmol, 5% mol) of CuCN was added, resulted suspension stirred for 20 min and 1.55 ml (12.8 mmol) of  $\text{Me}_2\text{SiCl}_2$  was added at one portion. Stirring was continued overnight, then mixture was poured into cold water, extracted with benzene (2\*100ml). Benzene solution was filtered through silicagel (Merck 60) and evaporated, yielded 4.7 g (83%) as light solid (mixture of *rac*- and *meso*-isomers).

**$^1\text{H}$ NMR ( $\text{CDCl}_3$ ):** 8.15, 7.75, 7.6, 7.45 (m,  $\Sigma$  20 H), 7.3 (s, 4H), 4.1 (d, 4H), 2.61 (s, 12H), 2.4 (d, 12H), -0.2 (s, 3H, *meso*-), -0.27 (s, 6H, *rac*-), -0.29 (s, 3H, *meso*-)

**e) (dimethyl)silanediybis(2,7-dimethyl-3*H*-cyclopenta[*a*]naphthalen-1-yl)ZrCl<sub>2</sub>**

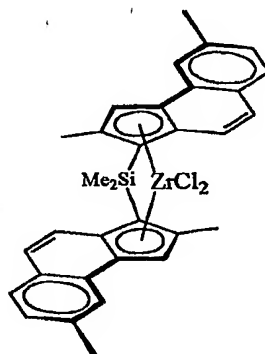


Lithium salt of **5** was prepared from 3 g (6.75mmol) of **5** and 8.8 ml (14.4 mmol) n-BuLi (Merck, 1.6 N solution in hexanes) in 40 ml of Et<sub>2</sub>O at -30 C. Then reaction mixture was warmed to 20 C, stirred 1 h and evaporated. Dry salt was suspended in 100 ml of pentane, then consecutively 1.86 g ZrCl<sub>4</sub> (7.9 mmol) and 5 ml of Et<sub>2</sub>O was added and mixture was stirred overnight. Precipitate was filtered off, washed with pentane and dried. Resulted compound was recrystallised from dichloromethane-ether mixture, afforded **6** as yellow-orange powder. Yield 2.5 g of **6** as a mixture of *rac*-/*meso*-=5/1.

**<sup>1</sup>H NMR (CD<sub>2</sub>Cl<sub>2</sub>):** 7.85, 7.6, 7.4, 7.32, 7.35, (m, Σ 20 H), 7.2 (s, 2H), 7.07 (s, 2H) 2.53 (s, 12H), 2.40 (s, 6H), 2.34 (s, 6H), 2.35 (s, 6H), 1.43 (s, 3H, *meso*-), 1.33 (s, 6H, *rac*-), 1.24 (s, 3H, *meso*-)

#### Example 1

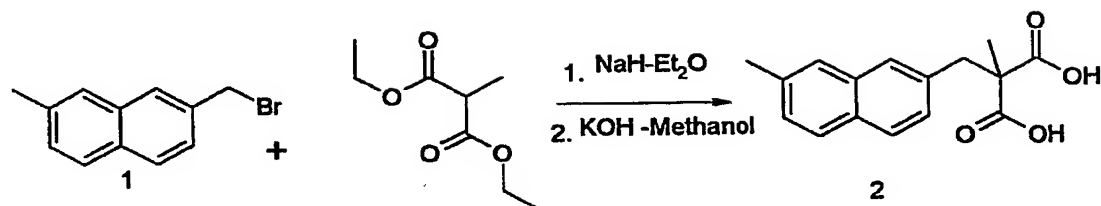
Synthesis of (dimethyl)silanediyilbis(2,8-dimethyl-3*H*-cyclopenta[*a*]naphthalen-1-yl)ZrCl<sub>2</sub> (**A1**)



(A1)

a) 2-methyl-2-[(7-methyl-2-naphthyl)methyl]malonic acid

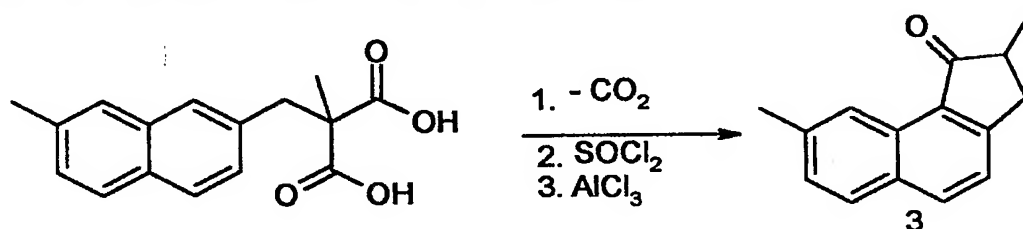




To a stirred suspension of 3.6 g NaH (90 mmol, 60 % in mineral oil) in 200 ml Et<sub>2</sub>O 16.2 ml (94 mmol) of diethyl 2-methylmalonate was added slowly with cooling. After 2 h stirring at 20 C, solution of 21.2 g (90 mmol) of 2-(bromomethyl)-7-methylnaphthalene (prepared according *Gorsane, M.; Martin, R. H.; Bull.Soc.Chim.Belg.; 94; 3; 1985; 205-214.*) in 20 ml of THF was added, resulting mixture was stirred overnight and decomposed by addition of saturated NH<sub>4</sub>Cl solution. Organic phase was separated, aqueous - extracted twice with 100 ml portions of ether. Combined extracts were evaporated, residue was dissolved in 150 ml methanol and solution of KOH (20 g, 360 mmol) was added slowly. Mixture was refluxed for 5 h, then evaporated to dryness and resulting semisolid was dissolved in warm water (300 ml). Solution was extracted three times with 100 ml portions of ether, then acidified carefully by addition of 10 % HCl. Precipitate of acid 2 was collected and dried, yielded 18.8 g (76 %) of yellowish powder.

<sup>1</sup>H NMR (CDCl<sub>3</sub>): 7.77 (qwart, 2H), 7.62 (s, 2H), 7.33 (m, 2H), 2.9 (s, 2H), 2.56 (s, 3H), 1.26 (s, 3H)

b) 2,8-dimethyl-2,3-dihydro-1H-cyclopenta[a]naphthalen-1-one

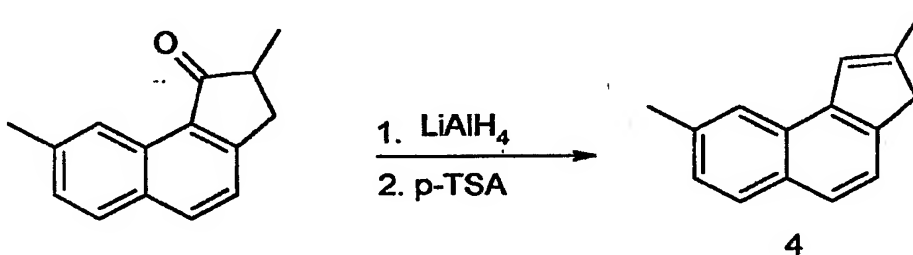


Acid 2 (15 g, 55 mmol) was heated to 180 C without solvent until gas evolving ceased (10 min), then reaction mixture was cooled, dissolved in benzene (50 ml) and evaporated. Oily residue was again dissolved in benzene (100 ml) and treated with SOCl<sub>2</sub> (12 ml, 165 mmol). Resulting solution was refluxed 3 h, evaporated to dryness and dissolved in 100 ml of dry CH<sub>2</sub>Cl<sub>2</sub>. This solution was added dropwise at 0 C to stirred suspension of 11.1 g (83 mmol) anhydrous AlCl<sub>3</sub> in 50 ml of CH<sub>2</sub>Cl<sub>2</sub>. Reaction mixture was stirred overnight, poured into ice-

5% HCl solution and extracted twice with 50 ml of  $\text{CH}_2\text{Cl}_2$ . Combined organic extracts were washed with  $\text{KHCO}_3$  solution, dried over  $\text{MgSO}_4$  and evaporated, afforded 9.6g (83 %) of **3** as brown solid.

**$^1\text{H}$ NMR ( $\text{CDCl}_3$ ):** 9.0 (s, 1H), 8.0 (d, 1H), 7.8 (d, 1H), 7.45 (t, 2H), 3.45 (qvar, 1H), 2.8 (m, 2H), 2.6 (s, 3H), 1.4 (d, 3H).

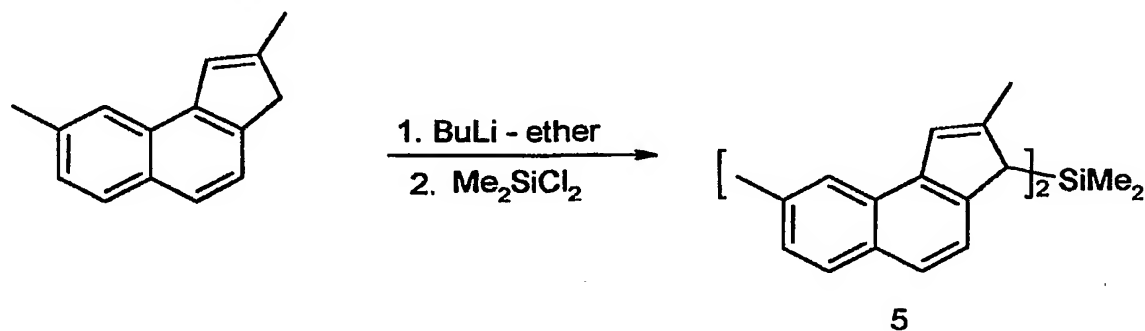
c) **2,8-dimethyl-3H-cyclopenta[*a*]naphthalene**



To a suspension of 0.32 g (8 mmol)  $\text{LiAlH}_4$  in 10 ml  $\text{Et}_2\text{O}$  solution of 3.5g (17 mmol) of **3** in ether (50 ml) was added slowly with stirring at 0 C. Reaction mixture was stirred at room temperature for 4 h, then decompose by addition of saturated  $\text{NH}_4\text{Cl}$  solution. Organic layer was separated, evaporated and resulting oil was dissolved in 250 ml of benzene. Small amount (100 mg) of p-TSA was added and solution was refluxed with Dean-Stark water trap for 1h. Reaction was monitored by TLC (benzene). Dark solution was cooled, washed with saturated  $\text{KHCO}_3$  solution, dried over  $\text{MgSO}_4$  and evaporated. Yield of **4** (two isomers) as light semisolid - 2.5 g (76 %).

**$^1\text{H}$ NMR ( $\text{CDCl}_3$ ):** 7.82 (t, 4H), 7.60 (d, 2H), 7.51 (d, 2H), 7.31 (t, 2H), 7.10 (s, 2H), 3.47 (s, 4H), 2.58 (s, 6H), 2.3(s, 6H)

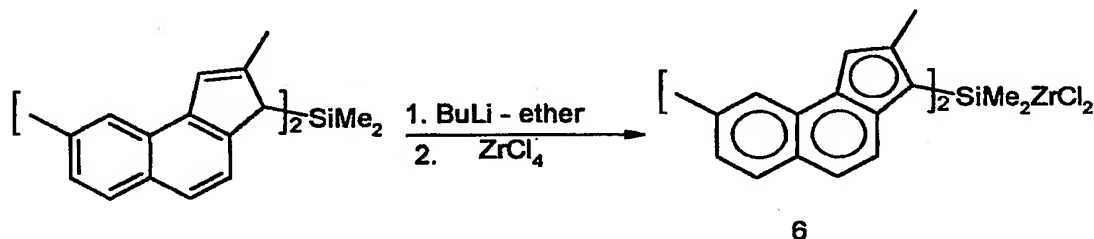
d) **bis(2,8-dimethyl-3H-cyclopenta[*a*]naphthalen-1-yl)(dimethyl)silane**



Lithium salt of 4 was prepared in usual manner from 2.0 g (10.3 mmol) of 4 and 6.8 ml (10.8 mmol) n-BuLi (Merck, 1.6 N solution in hexanes) in 30 ml Et<sub>2</sub>O at -30 C. Then reaction mixture was warmed to 20 C, stirred 2 h and again cooled to -70 C. At this temperature 60 mg (0.6 mmol, 5% mol) of CuCN was added, resulted suspension stirred for 20 min and 0.62 ml (5.13 mmol) of Me<sub>2</sub>SiCl<sub>2</sub> was added at one portion. Stirring was continued overnight, then mixture was poured into cold water, extracted with benzene (2\*100ml). Benzene solution was filtered through silica gel (Merck 60) and evaporated, yielded 1.8 g (79%) as light solid (mixture of *rac*- and *meso*-isomers).

**<sup>1</sup>H NMR (CDCl<sub>3</sub>):** 7.9, 7.8, 7.75, 7.55, 7.35 (m, Σ 20 H), 7.29 (s, 4H), 4.05 (d, 4H), 2.61 (s, 12H), 2.4 (d, 12H), -0.21 (s, 3H, *meso*-), -0.29 (s, 6H, *rac*-), -0.30 (s, 3H, *meso*-)

e) (dimethyl)silanediybis(2,8-dimethyl-3*H*-cyclopenta[*a*]naphthalen-1-yl)ZrCl<sub>2</sub>

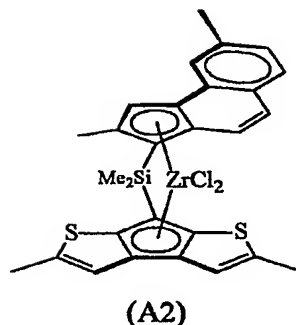


Lithium salt of 5 was prepared from 2.4 g (5.4 mmol) of 5 and 7 ml (11.2 mmol) n-BuLi (Merck, 1.6 N solution in hexanes) in 40 ml of Et<sub>2</sub>O at -30 C. Then reaction mixture was warmed to 20 C, stirred 1 h and evaporated. Dry salt was suspended in 50 ml of pentane, then consecutively 1.52 g ZrCl<sub>4</sub> (6.5 mmol) and 5 ml of Et<sub>2</sub>O was added and mixture was stirred overnight. Precipitate was filtered off, washed with pentane and dried. Resulted compound was recrystallised from dichloromethane-ether mixture, afforded 6 as yellow powder. Yield of 6 is 1.87 g as a mixture of *rac*-/*meso*- = 6/4.

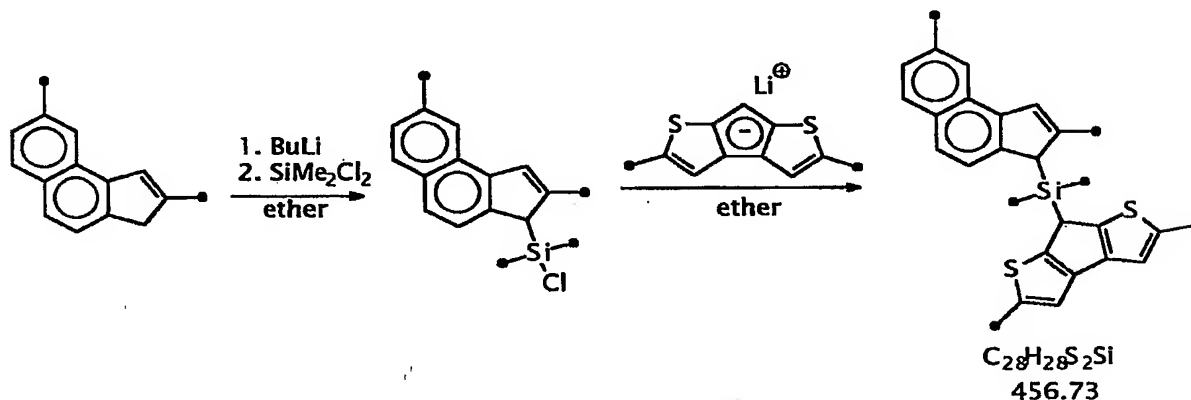
**<sup>1</sup>H NMR (CD<sub>2</sub>Cl<sub>2</sub>):** 7.65, 7.55, 7.35, 7.2, 7.35, 7.1 (m, Σ 24 H), 2.53 (s, 6H), 2.50 (s, 6H), 2.44 (s, 6H), 2.35 (s, 6H), 1.4 (s, 3H, *meso*-), 1.35 (s, 6H, *rac*-), 1.2 (s, 3H, *meso*-)

## Example 2

Synthesis of {μ-(η<sup>5</sup>-2,8-Dimethyl-3*H*-cyclopenta[*a*]naphth-3-yl)(η<sup>5</sup>-2,5-dimethyldithiophenocyclopentadien-7-yl)dimethylsilanediy] dichlorozirconium (IV) (A2)}



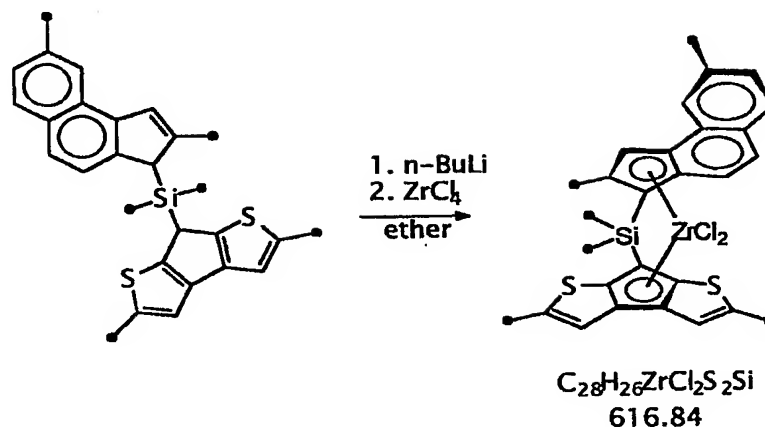
a) (2,8-Dimethyl-3*H*-cyclopenta[*a*]naphth-3-yl)(2,5-dimethyl-dithiopheno cyclopentadien-7-yl)dimethylsilane.



A solution of 2,8-dimethyl-3*H*-cyclopenta[*a*]naphthalene (0.43 g, 2.2 mmole) prepared as described above in ether (10 ml) was cooled to  $-40^{\circ}C$ , and *n*-BuLi in hexane (1.6M, 1.4 ml, 2.2 mmole) was added. Resulting mixture was allowed to warm to room temperature, stirred for 1 h, cooled to  $-60^{\circ}C$ , and  $SiMe_2Cl_2$  (0.35 ml, 2.9 mmole) was added. Resulting mixture was allowed to warm to room temperature, stirred for 16 h, evaporated and dried.

Dimethyldithiophenocyclopentadiene (0.45 g, 2.2 mmole) in ether (15 ml) was cooled to  $-40^{\circ}C$ , and *n*-BuLi in hexane (1.6M, 1.4 ml, 2.2 mmole) was added. Resulting mixture was allowed to warm to room temperature, stirred for 1 h, and added to suspension of dimethylchlorosilyl derivative of 2,8-dimethyl-3*H*-cyclopenta[*a*]naphthalene in 10 ml of ether at  $-60^{\circ}C$ . The resulting mixture was allowed to warm to room temperature, stirred for 16 h, evaporated and dried. The product was obtained by column chromatography (silica gel 60, hexane/ $CHCl_3$  8:1). The yield 0.82 g (82%) of yellow solid.

b)  $\{\mu-(\eta^5-2,8\text{-Dimethyl-3}H\text{-cyclopenta}[a]\text{naphth-3-yl})(\eta^5\text{-2,5-dimethyldithiophenocyclopentadien-7-yl})\text{dimethylsilanediyl}\}$  dichlor zirc nium (IV) (A2).

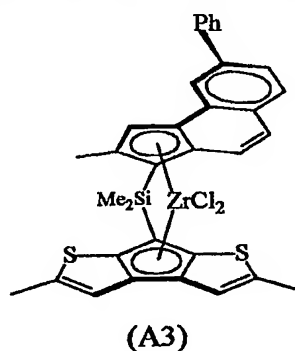


(2,8-dimethyl-3H-cyclopenta[a]naphth-3-yl)(2,5-dimethyl dithiopheno cyclopentadien-7-yl)dimethylsilane (0.82 g, 1.8 mmole) obtained in step a) was dissolved in Et<sub>2</sub>O (20 ml), cooled to -40°C, and n-BuLi (2.5 ml of 1.6M in hexane, 4 mmole) was added. Reaction mixture was allowed to warm to room temperature, stirred for 2 h, cooled to -60°C, and ZrCl<sub>4</sub> (0.44 g, 1.9 mmole) was added. Resulting mixture was allowed to warm to room temperature with stirring, stirred for additional 16 h. The resulting yellow precipitate was filtered off and recrystallized from CH<sub>2</sub>Cl<sub>2</sub> giving yellow-orange product. The yield 0.82 g (74%).

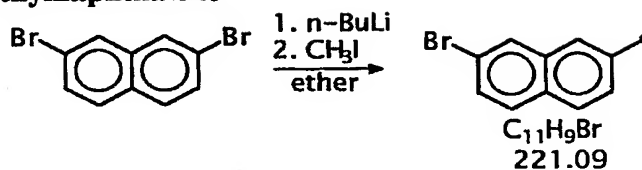
<sup>1</sup>H NMR (CD<sub>2</sub>Cl<sub>2</sub>, 20°C) δ: 7.81 (s, 1H); 7.59 (d, 1H); 7.51 (d, 1H); 7.30 (d, 1H); 7.12 (d, 1H) {aromatic C<sub>6</sub> rings}; 6.79 (s, 2H); 6.57 (s, 1H) {C<sub>5</sub> rings}; 2.60 (s, 3H); 2.53 (s, 3H); 2.43 (s, 3H); 2.40 (s, 3H); {C-CH<sub>3</sub>}; 1.32 (s, 3H); 1.18 (s, 3H) {Si-CH<sub>3</sub>}.

### Example 3

Synthesis of {μ-(η<sup>5</sup>-2-Methyl-8-phenyl-3H-cyclopenta[a]naphth-3-yl)(η<sup>5</sup>-2,5-dimethyldithiophenocyclopentadien-7-yl)dimethylsilanediyl} dichlorozirconium (IV) (A3).

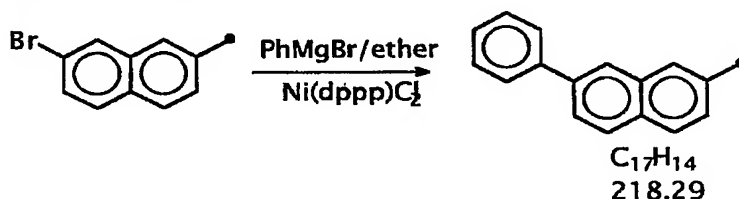


a) 2,7-Dibromonaphthalene was obtained by known method starting from 2,7-naphthalenediol [Porzi G., Concilio C., J.Organomet.Chem., 128 (1977), 95-98]

**b) 2-Bromo-7-methylnaphthalene**

Suspension of 2,7-dibromonaphthalene (61.4 g, 0.21 mole) in ether (400 ml) was cooled to -30°C, and n-BuLi (1.6M in hexane, 135 ml, 0.21 mole) was added. Reaction mixture was allowed to warm to room temperature, stirred for additional 2.5 h, cooled to -30°C, and CH<sub>3</sub>I (13.5 ml, 0.21 mole) was added. Reaction mixture was allowed to warm to room temperature, stirred for additional 16 h, treated by water (100 ml). Organic layer was separated, water layer was extracted by ether (6×100 ml). Combined organic fraction was evaporated, giving practically pure solid product. The yield 38.1 g (82%).

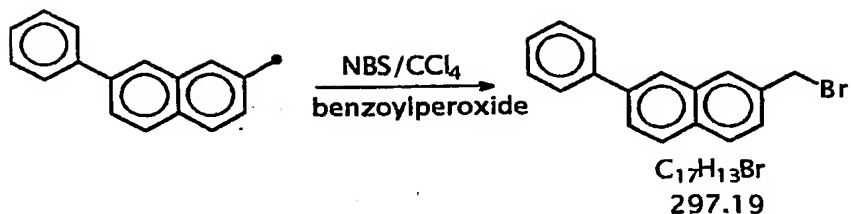
<sup>1</sup>H NMR (CDCl<sub>3</sub>, 20°C) δ: 7.93 (s, 1H); 7.70 (d, 1H); 7.52 (s, 1H); 7.50 (d, 1H); 7.35 (d, 1H) {aromatic C<sub>6</sub> rings}; 2.54 (s, 3H, -CH<sub>3</sub>).

**c) 2-Methyl-7-phenylnaphthalene**

Solution of 2-bromo-7-methylnaphthalene (10 g, 45 mmole) in ether (100 ml) was cooled to -0°C, and Ni(dppp)Cl<sub>2</sub> and solution of PhLi (obtained from 1.3 g of Mg and 5.6 ml of PhBr in 55 ml of ether) were added subsequently. Reaction mixture was allowed to warm to room temperature, stirred for additional 4 h with heating, cooled room temperature, stirred for additional 16 h, and treated by water (100 ml). Organic layer was separated, water layer was extracted by ether (3×50 ml). Combined organic fraction was evaporated, giving practically pure solid product. The yield 9.23 g (94%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 20°C) δ: 8.10 (s, 1H); 7.92 (d, 1H); 7.83-7.71 (group of m, 5H); 7.53 (t, 2H); 7.43 (t, 1H); 7.37 (d, 1H) {aromatic C<sub>6</sub> rings}; 2.58 (s, 3H, -CH<sub>3</sub>).

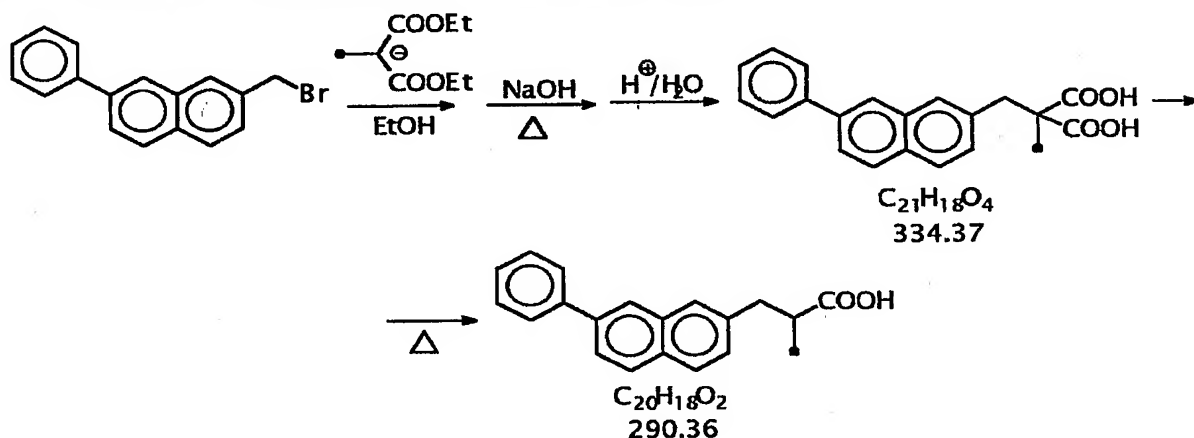
**d) 2-(Bromomethyl)-7-phenylnaphthalene**



2-Methyl-7-phenylnaphthalene (5.4 g, 25 mmole) and N-bromosuccinimide (4.4 g, 25 mmole) were suspended in  $\text{CCl}_4$  (60 ml). Benzoylperoxide (0.25 g) and  $\text{Br}_2$  (20 mkl) were added, the mixture was refluxed for 3 h, filtered, evaporated and dried giving practically pure product. The yield 7.4 g (~100%).

- 5  $^1\text{H}$  NMR ( $\text{CDCl}_3$ ,  $20^\circ\text{C}$ )  $\delta$ : 8.40 (s, 1H); 7.94-7.73 (group of m, 6H); 7.53 (m, 3H); 7.44 (t, 1H {aromatic  $\text{C}_6$  rings}); 4.71 (s, 2H,  $-\text{CH}_2$ ).

e) **2-Methyl-3-(7-phenyl-2-naphthyl)propanoic acid**



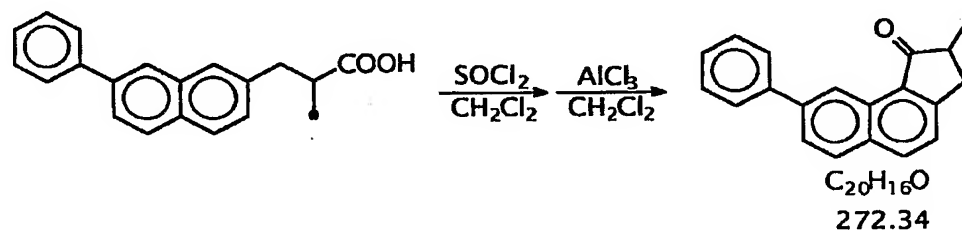
- 10 Diethylmethylmalonate (4.35 g, 25 mmole) was added to the solution of EtONa (1.7 g, 25 mmole) in ethanol (80 ml). The resulting mixture was stirred for 2 h, and 2-(Bromomethyl)-7-phenylnaphthalene (7.4 g, 25 mmole) was added. The resulting mixture was refluxed for 6 h, cooled, treated by NaOH (4 g in 10 ml of  $\text{H}_2\text{O}$ ) and refluxed for 6 h. After cooling, aq. HCl was added to pH~1. Resulting precipitate was filtered off, leading pure 2-methyl-2-[(7-phenyl-2-naphthyl)methyl]malonic acid. The yield 7.2 g (86%).

- 15  $^1\text{H}$  NMR ( $\text{DMSO}-d_6$ ,  $20^\circ\text{C}$ )  $\delta$ : 12.9 (broad, 2H,  $-\text{COOH}$ ); 8.12 (s, 1H); 7.97 (d, 1H); 7.86 (d, 1H); 7.80 (m, 4H); 7.52 (t, 2H); 7.41 (t, 1H); 7.35 (d, 1H) {aromatic  $\text{C}_6$  rings}; 3.28 (s, 2H,  $-\text{CH}_2$ ); 1.25 (s, 3H,  $-\text{CH}_3$ ).

2-Methyl-3-(7-phenyl-2-naphthyl)propanoic acid (6.25 g) was obtained by heating of dicarboxylic acid (150-160°C, 30 min).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 20°C) δ: 11.5-10 (broad, 1H, -COOH); 8.15 (s, 1H); 7.92 (d, 1H); 7.83 (d, 1H); 7.76 (m, 4H); 7.52 (t, 2H); 7.42 (t, 1H); 7.36 (d, 1H) {aromatic C<sub>6</sub> rings}; 3.30 (m, 1H); 2.90 (m, 2H) {-CHCH<sub>2</sub>-}; 1.25 (d, 3H, -CH<sub>3</sub>).

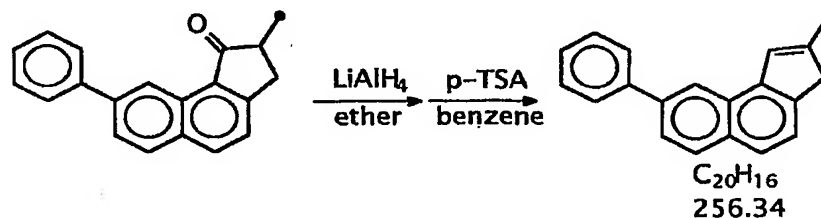
**f) 2-Methyl-8-phenyl-2,3-dihydro-1H-cyclopenta[*a*]naphthalen-1-one**



2-Methyl-3-(7-phenyl-2-naphthyl)propanoic acid (6.25 g, 21.5 mmole) was suspended in CH<sub>2</sub>Cl<sub>2</sub> (20 ml), and SOCl<sub>2</sub> (2.9 ml, 40 mmole) and 0.05 ml of DMF were added. The resulting mixture was stirred for 2 h at room temperature, refluxed for additional 1 h, evaporated and dried *in vacuo*. AlCl<sub>3</sub> (4.3 g, 33 mmol) was suspended in CH<sub>2</sub>Cl<sub>2</sub> (40 ml), and solution of obtained chloroanhydride in CH<sub>2</sub>Cl<sub>2</sub> (20 ml) was added at 0°C within 0.5 h. The resulting mixture was allowed to warm to room temperature, stirred for additional 2 h, and poured into ice/HCl (~200 g + 40 ml). The resulting mixture was extracted by CH<sub>2</sub>Cl<sub>2</sub> (4×50 ml). Combined organic phase was washed by aq. KHCO<sub>3</sub>, dried over MgSO<sub>4</sub>, evaporated and dried *in vacuo* giving practically pure solid product. The yield 5.45 g (92%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 20°C) δ: 9.48 (s, 1H); 8.07 (d, 1H); 7.70 (d, 1H); 7.85 (m, 3H); 7.53 (m, 3H); 7.43 (t, 1H) {aromatic C<sub>6</sub> rings}; 3.50 (m, 1H); 2.85 (m, 2H) {-CHCH<sub>2</sub>-}; 1.41 (d, 3H, -CH<sub>3</sub>).

**g) 2-Methyl-8-phenyl-3H-cyclopenta[*a*]naphthalene**



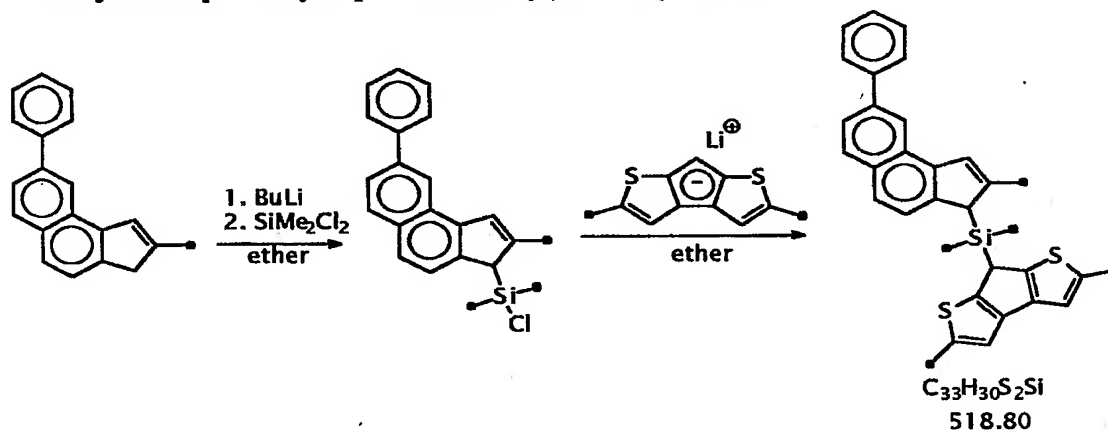
2-Methyl-8-phenyl-2,3-dihydro-1H-cyclopenta[*a*]naphthalen-1-one (5.45 g, 20 mmole) in Et<sub>2</sub>O (50 ml) was added dropwise to cooled (-40°C) suspension of LiAlH<sub>4</sub> (0.23 g, 6 mmole) in Et<sub>2</sub>O (50 ml). The resulting mixture was allowed to warm to room temperature and stirred for



additional 2 h. Then H<sub>2</sub>O (10 ml) and 10M HCl (5 ml) were added, the resulting mixture was poured into CH<sub>2</sub>Cl<sub>2</sub> (300 ml). The organic phase was washed by water (50 ml), 5% aq. KHCO<sub>3</sub> (50 ml), dried over MgSO<sub>4</sub> and evaporated giving white crystalline alcohol. The 250 ml round-bottomed flask was sparged with argon; benzene (100 ml) and p-TSA (0.2 g) were added, and resulting solution was refluxed with Dine-Stark head with stirring (control by TLC, benzene/EtOAc 4:1) within 1.5 h. Then the resulting yellow solution was washed by water, aq. KHCO<sub>3</sub>, water, dried over MgSO<sub>4</sub>, passed through small amount of silica gel and evaporated giving 4.8 g (94%) of the product.

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 20°C) δ: 8.30 (s, 1H); 7.98 (d, 1H); 7.82 (dd, 2H); 7.75 (d, 1H); 7.68 (d, 1H); 7.60 (d, 1H); 7.55 (t, 2H); 7.44 (d, 1H); 7.20 (s, 1H) {-CH=}; 3.51 (s, 2H, -CH<sub>2</sub>-); 2.33 (s, 3H, -CH<sub>3</sub>).

**h) (2-Methyl-8-phenyl-3*H*-cyclopenta[*a*]naphth-3-yl)(2,5-dimethyldithiophenocyclopentadien-7-yl)dimethylsilane.**

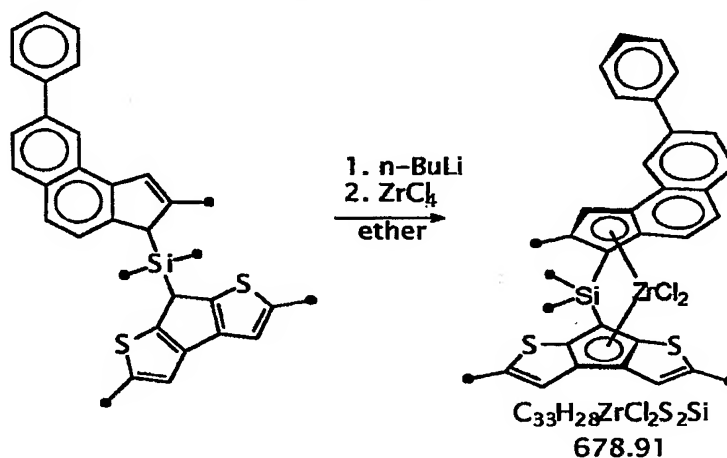


Solution of 2-methyl-8-phenyl-3*H*-cyclopenta[*a*]naphthalene (2.56 g, 10 mmole) in ether (50 ml) was cooled to -40°C, and n-BuLi in hexane (1.6M, 6.3 ml, 10 mmole) was added. Resulting mixture was allowed to warm to room temperature, stirred for 1 h, cooled to -60°C, and SiMe<sub>2</sub>Cl<sub>2</sub> (1.33 ml, 11 mmole) was added. Resulting mixture was allowed to warm to room temperature, stirred for 16 h, evaporated and dried. Dimethyldithiophenocyclopentadiene (2.06 g, 10 mmole) in ether (40 ml) was cooled to -40°C, and n-BuLi in hexane (1.6M, 6.3 ml, 10 mmole) was added. Resulting mixture was allowed to warm to room temperature, stirred for 1 h, and added to suspension of dimethylchlorosilyl derivative of 2-methyl-8-phenyl-3*H*-cyclopenta[*a*]naphthalene in 50 ml of ether at -60°C. The resulting mixture was allowed to

warm to room temperature, stirred for 16 h, evaporated and dried. The product was obtained by crystallization from hexane as a single isomer. The yield 2.28 g (44%).

<sup>1</sup>H NMR (CDCl<sub>3</sub>, 20°C) δ: 8.39 (s, 1H); 7.99 (d, 1H); 7.81 (dd, 2H); 7.78 (d, 1H); 7.63 (m, 2H); 7.56 (t, 2H); 7.44 (t, 1H); 7.36 (s, 1H); 6.94 (s, 1H); 6.90 (s, 1H) {-CH=}; 4.19 (s, 1H); 4.10 (s, 1H) {>CH-}; 2.63 (s, 3H); 2.58 (s, 3H); 2.42 (s, 3H) {C-CH<sub>3</sub>}; -0.31 (s, 3H); -0.33 (s, 3H) {Si-CH<sub>3</sub>}.

i) {μ-(η<sup>5</sup>-2-Methyl-8-phenyl-3*H*-cyclopenta[*a*]naphth-3-yl)(η<sup>5</sup>-2,5-dimethyldithiophenocyclopentadien-7-yl)dimethylsilanediyl} dichlorozirconium (IV).



(2-Methyl-8-phenyl-3*H*-cyclopenta[*a*]naphth-3-yl)(2,5-dimethyl-dithiophenocyclopentadien-7-yl)dimethylsilane (2.28 g, 4.39 mmole) was suspended in Et<sub>2</sub>O (60 ml), cooled to -40°C, and n-BuLi (5.6 ml of 1.6M in hexane, 9 mmole) was added. Reaction mixture was allowed to warm to room temperature, stirred for 2 h, cooled to -60°C, and ZrCl<sub>4</sub> (1.05 g, 4.5 mmole) was added. Resulting mixture was allowed to warm to room temperature with stirring, stirred for additional 16 h. The resulting yellow precipitate was filtered off and purified by 20-times extraction by CH<sub>2</sub>Cl<sub>2</sub> with subsequent concentration of the solution giving yellow-orange product. The yield 1.97 g (66%).

#### Polymerization examples

##### General procedure

The catalyst mixture was prepared by dissolving the amount of the metallocene indicated in table 1 in 5 ml of toluene with the proper amount of the methylalumoxane (MAO) solution

(30% by weight in toluene) (Al/Zr molar ratio=500) obtaining a solution which was stirred for 10 min at room temperature before being injected into the autoclave.

2 mmol of Al(*i*-Bu)<sub>3</sub> (as a 1M solution in hexane) and 700 g of propylene were charged at room temperature in a 2.4-L jacketed stainless-steel autoclave, equipped with magnetically driven stirrer and a 35-mL stainless-steel vial, connected to a thermostat for temperature control, previously purified by washing with an Al(*i*-Bu)<sub>3</sub> solution in hexanes and dried at 50°C in a stream of propylene. The autoclave was then thermostatted at 70°C, and then the toluene solution containing the catalyst/cocatalyst mixture was injected in the autoclave by means of nitrogen pressure through the stainless-steel vial, and the polymerization carried out at constant temperature for 1 hour. The polymerization was stopped by pressurizing CO into the reactor. After venting the unreacted monomer and cooling the reactor to room temperature, the polymer was dried under reduced pressure at 60 °C. The polymerization results are reported in table 1.

Table 1				
Ex	metall. (mg)	Activity Kg/g <sub>cat</sub> ·h	η dL/g	Tm(II) (°C)
1	A1 (1) <sup>a)</sup>	319	2.1	144.7
2*	C1(0.5)	220	1.8	144
3*	C2 (0.5) <sup>b)</sup>	200	2.1	143.5

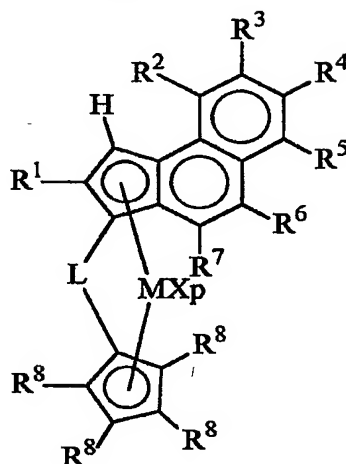
\* comparative

- 15      a) mixture of rac meso isomers (rac:meso 6:4);  
           b) mixture of rac meso isomers (rac:meso 5:1);

From table 1 clearly results that the compound A1 even if it is used in rac, meso mixture (the meso form has an activity lower or it is inactive with respect to the rac form) shows a polymerization activity higher than the compound C1 and C2.

## Claims

1. A metallocene compound of formula (I):



(I)

wherein:

M is an atom of a transition metal selected from those belonging to group 3, 4, 5, 6 or to the lanthanide or actinide groups in the Periodic Table of the Elements;

p is an integer from 0 to 3, being equal to the formal oxidation state of the metal M minus 2; X, same or different, is a hydrogen atom, a halogen atom, or a R, OR, OSO<sub>2</sub>CF<sub>3</sub>, OCOR, SR, NR<sub>2</sub> or PR<sub>2</sub> group, wherein R is a C<sub>1</sub>-C<sub>40</sub> hydrocarbon group optionally containing

heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; or two X can optionally form a substituted or unsubstituted butadienyl radical or a OR'O group wherein R' is a divalent radical selected from C<sub>1</sub>-C<sub>40</sub> alkylidene, C<sub>6</sub>-C<sub>40</sub> arylidene, C<sub>7</sub>-C<sub>40</sub> alkylarylidene and C<sub>7</sub>-C<sub>40</sub> arylalkylidene radicals;

L is a divalent bridging group selected from C<sub>1</sub>-C<sub>20</sub> alkylidene, C<sub>3</sub>-C<sub>20</sub> cycloalkylidene, C<sub>6</sub>-C<sub>20</sub> arylidene, C<sub>7</sub>-C<sub>20</sub> alkylarylidene, or C<sub>7</sub>-C<sub>20</sub> arylalkylidene radicals optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements, and a silylidene radical containing up to 5 silicon atoms;

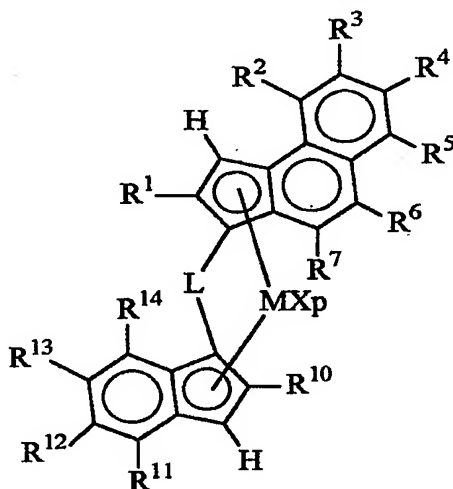
R<sup>1</sup> is a C<sub>1</sub>-C<sub>40</sub> hydrocarbon group optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;

R<sup>3</sup> is a C<sub>1</sub>-C<sub>40</sub> hydrocarbon group optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;

- $R^2$ ,  $R^4$  and  $R^5$ , equal to or different from each other, are hydrogen atoms or  $C_1$ - $C_{40}$  hydrocarbon groups optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; with the proviso that least one among  $R^2$ ,  $R^4$  and  $R^5$  is a hydrogen atom;
- 5  $R^3$  with  $R^4$  and/or  $R^4$  with  $R^5$  can also join to form a aliphatic or aromatic 3-7 membered ring optionally containing heteroatoms belonging to groups 13-16 of the Periodic Table of the Elements; said ring can bear one or more hydrocarbon substituents having from 1 to 20 carbon atoms;
- $R^6$  and  $R^7$ , equal to or different from each other, are hydrogen atoms or  $C_1$ - $C_{40}$  hydrocarbon groups optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;
- 10  $R^8$ , equal to or different from each other, are hydrogen atoms or  $C_1$ - $C_{50}$  hydrocarbon groups optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; two or more  $R^8$  groups can also join together to form one or more 3-7
- 15 membered ring said rings contain at least one heteroatom belonging to groups 13-16 of the Periodic Table of the Elements; said rings can be further substituted with  $C_1$ - $C_{20}$  hydrocarbon groups optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements.
2. The metallocene compound of formula (I) according to claim 1 wherein M is titanium, zirconium or hafnium; p is 2; R is a linear or branched, cyclic or acyclic,  $C_1$ - $C_{40}$ -alkyl,  $C_2$ - $C_{40}$  alkenyl,  $C_2$ - $C_{40}$  alkynyl,  $C_6$ - $C_{40}$ -aryl,  $C_7$ - $C_{40}$ -alkylaryl or  $C_7$ - $C_{40}$ -arylalkyl radicals; optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; X is a hydrogen atom, a halogen atom or a R group; L is a group  $Z(R'')_2$  wherein Z is a carbon or a silicon atom, and  $R''$  is a linear or branched, cyclic or acyclic,  $C_1$ - $C_{10}$ -alkyl,
- 20  $C_2$ - $C_{10}$  alkenyl,  $C_2$ - $C_{10}$  alkynyl,  $C_6$ - $C_{10}$ -aryl,  $C_7$ - $C_{10}$ -alkylaryl or  $C_7$ - $C_{10}$ -arylalkyl radicals optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;
- 25 3. The metallocene compound of formula (I) according to claims 1 or 2 wherein  $R^1$  is a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl radical;  $R^3$  is a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl or a  $C_6$ - $C_{40}$ -aryl, radical;  $R^2$ ,  $R^4$  and  $R^5$  are hydrogen
- 30

atoms; and  $R^6$  and  $R^7$  are hydrogen atoms or linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl radicals.

4. The metallocene compound according to anyone of claims 1-3 having formula (II)



(II)

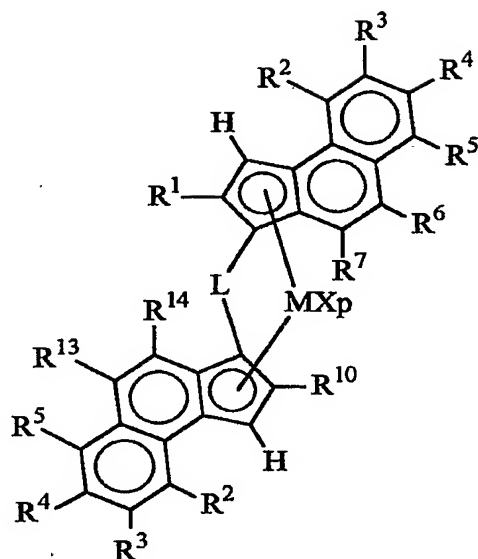
wherein M, X, p, L,  $R^1$ ,  $R^2$ ,  $R^3$ ,  $R^4$ ,  $R^5$ ,  $R^6$  and  $R^7$  have the meaning described in claims 1-3;

$R^{10}$  is, a hydrogen atom or  $C_1$ - $C_{40}$  hydrocarbon group optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;

$R^{11}$ ,  $R^{12}$ ,  $R^{13}$  and  $R^{14}$ , equal to or different from each other, are hydrogen atoms or  $C_1$ - $C_{40}$  hydrocarbon groups optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; two adjacent  $R^{11}$ ,  $R^{12}$ ,  $R^{13}$  and  $R^{14}$  groups can also join to form a 3-7 membered ring optionally containing heteroatoms belonging to groups 13-16 of the Periodic Table of the Elements; said ring can bear one or more hydrocarbon substituents having from 1 to 20 carbon atoms.

The metallocene compound according to claim 4 wherein  $R^{10}$  is a linear or branched  $C_1$ - $C_{20}$ -alkyl radical;  $R^{11}$  is a  $C_6$ - $C_{40}$ -aryl,  $C_7$ - $C_{40}$ -alkylaryl or  $C_7$ - $C_{40}$ -arylalkyl radical or form with  $R^{12}$  a phenyl ring that can be substituted with hydrocarbon groups having from 1 to 20 carbon atoms;  $R^{12}$  is a hydrogen atoms or form with  $R^{11}$  3-7 membered ring as explained above;  $R^{14}$  and  $R^{13}$  are hydrogen atoms or  $C_1$ - $C_{20}$  alkyl radicals.

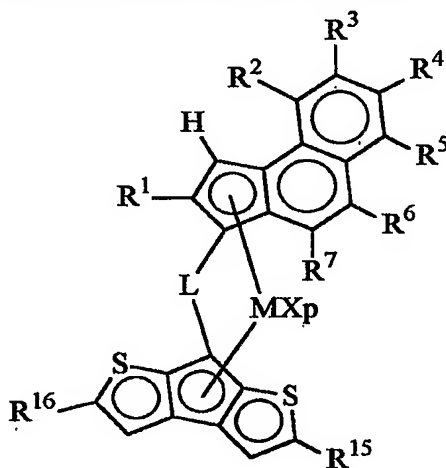
6. The metallocene compound according to claims 4 or 5 having formula (III)



(III)

wherein M, X, p, L, R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, R<sup>5</sup>, R<sup>6</sup>, R<sup>7</sup>, R<sup>10</sup>, R<sup>13</sup> and R<sup>14</sup> have the meaning described in claim 1-5.

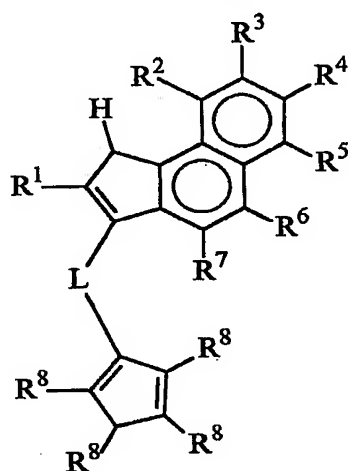
7. The metallocene compound according to anyone of claims 1-3 having formula (IV)



(IV)

wherein M, X, p, L, R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, R<sup>5</sup>, R<sup>6</sup> and R<sup>7</sup> have the meaning described in claims 1-3;  
 R<sup>15</sup> and R<sup>16</sup>, equal to or different from each other, are hydrogen atoms or C<sub>1</sub>-C<sub>40</sub>  
 hydrocarbon groups optionally containing heteroatoms belonging to groups 13-17 of the  
 Periodic Table of the Elements;

8. The metallocene compound according to claim 7 wherein  $R^{15}$  and  $R^{16}$  are linear or branched  $C_1$ - $C_{40}$ -alkyl radicals optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements.
9. A process for preparing a metallocene compound of formula (I) comprising the following steps:
- 5 (a) contacting the compound of formula (Ia)



(Ia)

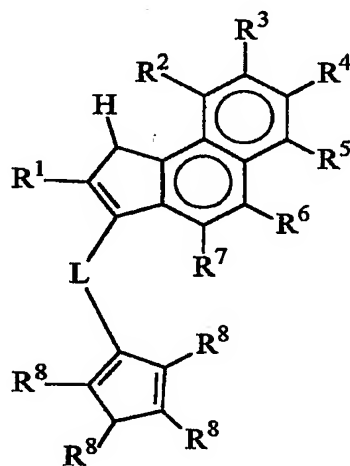
and/or its double bond isomers

wherein  $R^1$ ,  $R^2$ ,  $R^3$ ,  $R^4$ ,  $R^5$ ,  $R^6$ ,  $R^7$ ,  $R^8$  and L have the meaning described in claims 1-3 with a base selected from  $T_jB$ ,  $TMgT^1$ , sodium and potassium hydride, metallic sodium and potassium, wherein B is an alkaline or alkali-earth metal; and j is 1 or 2, j being equal to 1 when B is an alkaline metal, preferably lithium, and j being equal to 2 when B is an alkali-earth metal; T is a linear or branched, cyclic or acyclic,  $C_1$ - $C_{20}$ -alkyl,  $C_6$ - $C_{20}$ -aryl,  $C_7$ - $C_{20}$ -alkylaryl or  $C_7$ - $C_{20}$ -arylalkyl radical, optionally containing one or more Si or Ge atoms; preferably T is methyl or butyl radical;  $T^1$  is an halogen atom or a group  $OR'''$  wherein  $R'''$  is a linear or branched, cyclic or acyclic,  $C_1$ - $C_{40}$ -alkyl,  $C_6$ - $C_{40}$ -aryl,  $C_7$ - $C_{40}$ -alkylaryl or  $C_7$ - $C_{40}$ -arylalkyl radical, optionally containing one or more heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; wherein the molar ratio between said base and the ligand of the formula (Ia) and is at least 2:1; excess of said base can be used; and



- b) contacting the product obtained in step a) with a compound of formula  $MX_{p+2}$  wherein M, X and p have the meaning described in claims 1-3.

10. A ligand of formula (Ia)

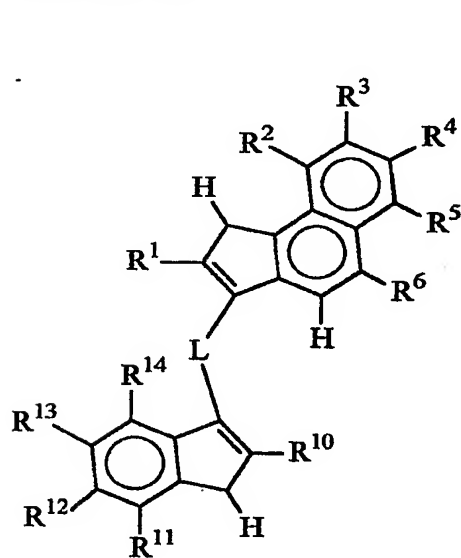


(Ia)

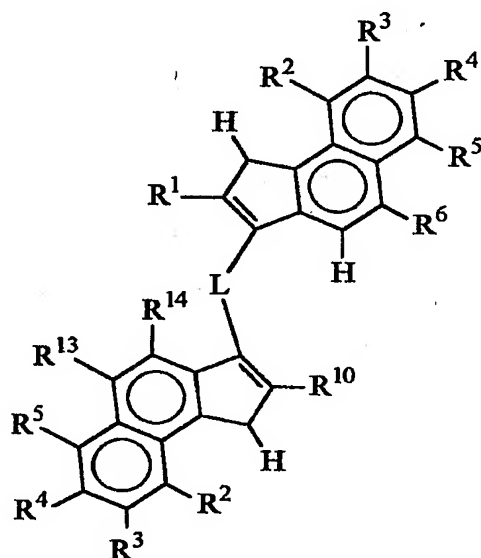
and/or its double bond isomers

5 wherein  $R^1, R^2, R^3, R^4, R^5, R^6, R^7, R^8$  and L have the meaning described in claims 1-3.

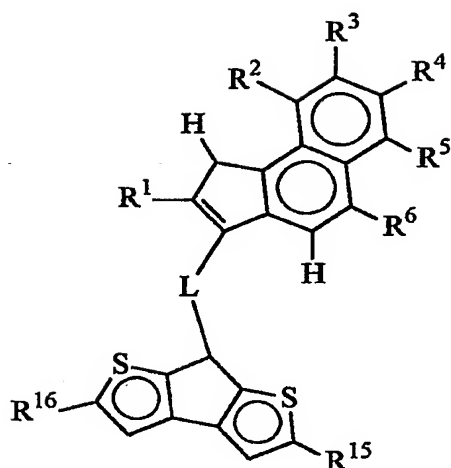
11. The ligand according to claim 12 having formulas (IIa), (IIIa) and (IVa) and/or their double bonds isomers



(IIa)



(IIIa)



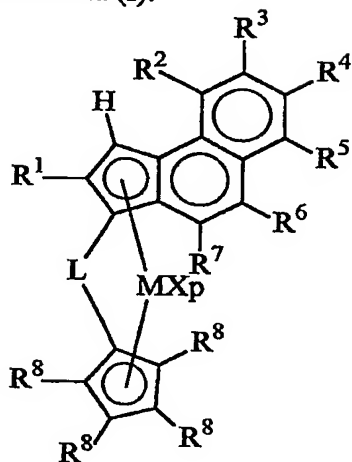
(IVa)

wherein L, R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, R<sup>4</sup>, R<sup>5</sup>, R<sup>6</sup>, R<sup>7</sup>, R<sup>8</sup>, R<sup>9</sup>, R<sup>10</sup>, R<sup>11</sup>, R<sup>12</sup>, R<sup>13</sup>, R<sup>14</sup>, R<sup>15</sup> and R<sup>16</sup>, have been described in claims 1-8.

12. A catalyst system obtainable by contacting:
  - a) at least a metallocene compound of formula (I);
  - b) at least an alumoxane or a compound able to form an alkylmetallocene cation; and
  - c) optionally an organo aluminum compound.
13. The catalyst system according to claim 12 wherein the metallocene compound of point a) is selected from the compounds of formulas (II), (III) and (IV).
14. A process for (co)polymerizing olefins containing from 2 to 20 carbon atoms comprising contacting one or more of said olefins under polymerization conditions in the presence of the catalyst system of claims 12 and 13.
15. The process according to claim 14 wherein the olefins are alpha-olefins containing from 2 to 20 carbon atoms.
16. The process according to claim 16 wherein are propylene, ethylene or 1-butene are (co)polymerized

**Abstract**

A metallocene compound of formula (I):



(I)

wherein:

M is an atom of a transition metal; X, same or different, is a hydrogen atom, a halogen atom, or a R,  
 5 OR,  $OSO_2CF_3$ ,  $OCOR$ ,  $SR$ ,  $NR_2$  or  $PR_2$  group, wherein R is a  $C_1$ - $C_{40}$  hydrocarbon group; L is a  
 divalent bridging group;  $R^1$ , is a  $C_1$ - $C_{40}$  hydrocarbon group;  $R^3$  is a  $C_1$ - $C_{40}$  hydrocarbon group;  
 $R^2$ ,  $R^4$ ,  $R^5$ ,  $R^6$ ,  $R^7$  and  $R^8$ , equal to or different from each other, are hydrogen atoms or  $C_1$ - $C_{40}$   
 hydrocarbon groups.